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- [X] CONTRACT NO. F04701-90-C-0070
- [ ] IR&D
- [ ] OTHER

DOCUMENT NO. D290-75303-2, Vol. I MODEL IUS

TITLE IUS Program Shock Analyses

MICROFILMED 5-2-85

19961119 043

ORIGINAL RELEASE DATE 82FEB03

ISSUE NO. TO

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IUS/SI Document Release
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DTIC QUALITY INSPECTED 4

Rev D 930406

DO 6000 2160 ORIG. 4/71

ABSTRACT

This document contains shock analyses, test data and flight data from the IUS Program. The analyses and data were used to demonstrate compliance with environmental requirements. The document consists of 3 volumes.

R

KEY WORDS

analyses
flight data
IUS
pyroshock
qualification
shock
shock spectra
Space Transportation System
TITAN
test data

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ACRONYMS

AFTA	Aft Frame Tilt Actuator
ASE	Airborne Support Equipment
CI	Critical Item
CQT	Component Qualification Test
DDAS	Digital Data Analysis System
DOD	Department of Defense
EMU	Environmental Measurement Unit
ESS	Equipment Support Section
FTS	Flight Termination System
ICD	Interface Control Drawing
IDA	Isolation Diode Assembly
IUS	Inertial Upper Stage
PCU	Power Control Unit
PDU	Power Distribution Unit
PSU	Pyro Switching Unit
PTU	Power Transfer Unit
P95/50	95^{th} Percentile Probability, 50% Confidence
RCS	Reaction Control System
REM	Rocket Engine Motor
RIMU	Redundant Inertial Measurement Unit
QTV	Qualification Test Vehicle
S&A	Safe and Arm
S/C	Spacecraft
SCU	Signal Conditioning Unit
SGLS	Space Ground Link Subsystem
SIU	Signal Interface Unit
SRM	Solid Rocket Motor
STS	Space Transportation System (Space Shuttle)
TIU	Titan Interface Unit
TVC	Thrust Vector Control
T34D	Titan Launch Vehicle Configuration Used for IUS Launch
WBDI	Wide Band Data Interlever

1.0 Introduction

1.1 Purpose

This document presents analyses which demonstrate that the IUS vehicle, ASE and components are qualified to mechanical shock environment requirements.

1.2 Scope

Section 2 presents the shock design requirements associated with the IUS launch vehicles (T34D and Space Shuttle), spacecraft payloads, transportation and handling and IUS pyrotechnic shock environments. Section 2 also describes the analysis methods used in this report. Section 3 contains the analyses which demonstrate qualification of the IUS vehicle, the IUS ASE and IUS components. Section 4 presents analyses to demonstrate that the interface shock design requirements are valid.

1.3 IUS Configuration

Two basic IUS configurations have been developed during the FSD program (1) the DOD-STS 2-Stage and (2) the DOD-T34D 2-Stage. These configurations are described on Figures 1.0-1 through 1.0-6. The DOD-T34D configuration is launched aboard a Titan T34D vehicle supported by a Super*Zip separation ring at the SRM-1 aft attachment ring. The DOD-STS configuration is launched in the STS space shuttle payload bay with forward and aft supports as illustrated in Figure 1.0-7. In both configurations the spacecraft is attached at the Spacecraft Interface Ring on the forward end of the equipment support section (ESS).

2.0 Shock Environment Requirements and Analysis Methods

2.1 IUS Vehicle Shock Requirements

2.1.1 T34D Payload Fairing Separation Shock

The shock environment at the IUS/T34D interface (per Reference 5.2) resulting from T34D payload fairing separation is described by the shock spectrum shown in Figure 2.1.1.-1.

2.1.2 Orbiter Induced Pyrotechnic Shock

The shock environment at the IUS ASE/Orbiter interface (per Reference 5.1) resulting from pyrotechnic events on the orbiter is described by the shock spectrum shown in Figure 2.1.2-1. See paragraph 4.4

2.1.3 Spacecraft Pyrotechnic Events Induced Shock Environment

The shock environment on the IUS vehicle resulting from Spacecraft pyrotechnic events is defined (per Reference 5.1) by the shock spectra shown in Figure 2.1.3-1.

2.2 Component Shock Qualification Test (CQT) Requirements

2.2.1 Non-Operating Transportation and Handling Shock

Per Reference 5.1, all IUS components shall be designed to withstand a 20 g terminal sawtooth shock pulse of 0.011 second duration in each direction of three orthogonal axes (6 directions).

2.2.2 Pyrotechnic Shock

Per Reference 5.3, all IUS components shall be qualified to a shock environment 6 dB greater than the maximum expected pyrotechnic shock environment defined by a shock spectrum (Q = 10) between 100 Hz and 10,000 Hz at 1/6 octave increments.

The IUS vehicle/ASE contains four pyrotechnic devices, (1) I/II Staging Separation Nuts, (2) Super*Zip Separation Joint, (3) Pin Pullers and (4) Safe and Arm Devices. Only two of these devices create a significant pyrotechnic shock for IUS components, the separation nuts and the Super*Zip. The Safe and Arm devices are located on vibration isolators, thus alleviating the S&A produced shock environment. The pin pullers are not located in close proximity to any component except the ASE AFTA.

The pyroshock CQT requirements were determined primarily from two pyroshock development tests (References 5.4 and 5.5). The pyroshock CQT requirements were modified for some components mounted on vibration isolators. Pyroshock CQT requirements for three components were modified as a result of pyroshock environment measured during the QTV pyroshock qualification test (the SIU, SCU and the RF Switch). Pyroshock CQT requirements for the IUS components are shown on Figures 2.2.2-1 through 2.2.2-9. Table 2.2.2-A contains a list of components and corresponding pyroshock CQT requirement.

2.3 Analysis Methods

The purpose of this paragraph is to describe briefly the analysis methods used in evaluation and qualification of the IUS vehicle and components. A detailed description with theoretical background, where applicable, is provided in Reference 5.6.

2.3.1 Shock Spectrum

The shock spectrum is a method of describing transient acceleration (Shock) environments in the frequency domain. The shock spectrum is not a precise description of the shock environment (such as the fourier transform), which would allow duplication of the environment. Rather, the shock spectrum represents the damage potential of the environment on structural elements at various frequencies (Reference 5.7).

Reference 5.3, MIL-STD-1540A, requires that the pyroshock environment be defined by a shock spectrum using a damping value of .05 critical damping (Q = 10) between frequencies of 100 Hz and 10,000 Hz at 1/6 octave intervals. Two systems have been used to produce shock spectra of IUS equipment environments complying with the MIL-STD-1540A requirements, (1) the DDAS and (2) the Hewlett Packard 5451C. Both systems use a digital computer to calculate the shock spectrum but differ in that the DDAS system calculates the transient response time history for each frequency of the spectrum while the HP 4541C uses a fast fourier transform algorithm. The shock spectra produced by the two systems are essentially identical. Reference 5.6 includes a discussion of shock spectra and the differences between the DDAS and HP 5451C analysis methods. Figure 2.3.1-1 shows the procedure used to obtain shock spectra using the HP 5451C and to create shock spectra data files on the VAX 11/780 computer. Reference 5.6 includes a detail description of the programs, HREAD, FSSREAD and SSMERGE.

2.3.2 Shock Spectra Statistics Methods

Reference 5.3, MIL-STD-1540A, requires that the maximum expected shock environment be defined by the 95th percentile, 50% confidence limits (P95/50) of the measured shock data. Calculation of the P95/50 levels require determination of the mean and standard deviation at each frequency for all shock spectra of applicable measured data. Two programs have been written for use with the VAX 11/780 computer and the STS Interactive Computer Graphics facility for calculating the mean, envelope and P95/50 levels for any number of shock spectra. One program is based on the assumption that test data is normally distributed. The second program is based on the assumption that the test data fits a log-normal distribution. All P95/50 levels derived for the IUS shock environments are based on a log-normal distribution. A detailed description of these programs as well as a discussion of log-normal vs. normal distribution fit of test data is included in Reference 5.6.

2.3.3 Pyroshock Environment Prediction Methods

2.3.3.1 NASA Pyroshock Predictor

Pyroshock source and attentuation characteristics defined in Reference 5.8 were used to supplement test data for prediction of pyroshock environments.

2.3.3.2 Pyroshock Attenuation Across Stage I Motor

A significant consideration in showing qualification of the IUS vehicle and components for pyroshock environments is the attenuation of high frequency shock across the Stage I motor. Data was measured during the IUS/T34D Separation Subsystem Test (Reference 5.10) showing the attenuation of pyroshock between the aft skirt and 1/2 the distance across the Stage I motor. The transverse axis attenuation, indicated by a comparison of radial axis measurements, is roughly constant across the entire frequency range between 100 and 10,000 Hz at 20 dB or greater. The axial axis attenuation is dependent upon frequency with a minimum of 7.0 dB attenuation between 3000 and 3500 Hz. A plot of the pyroshock attenuation vs. frequency for 1/2 the distance across the Stage I motor is shown in Figure 2.3.3.2-1.

2.3.3.3 ESS Pyroshock Attenuation

A series of programs were written for use with the VAX 11/780 computer Interactive Graphics for the purpose of using the QTV shock test data to calculate shock

attenuation spectra and predicting component shock levels due to a shock at the spacecraft interface. The program names and a flow diagram of their use is shown in Figure 2.3.3.3-1. A detailed description of these programs is contained in Reference 5.6.

2.3.3.4 Transfer Function Calculation

The vibration transfer function across vibration/shock isolators is calculated using vibration PSD data measured on both sides of isolators. A program written for use with the VAX 11/780 computer and the STS Interactive Computer Graphics facility is used to calculate the transfer function (Figure 2.3.4-1). The transfer function (T_f) consists of a plot vs. frequency (f) of the solution of the following ratio:

$$T_f = \left[\frac{PSD_f\ (\text{Response})}{PSD_f\ (\text{Input})}\right]^{\frac{1}{2}}$$

The vibration transfer function was used to evaluate shock attenuation characteristics of isolators for which no shock data was available (TIU).

3.0 Shock Environment Qualification Analyses

3.1 IUS Vehicle Qualification

3.1.1 Payload Fairing Separation Shock A

3.1.1.1 T34D Configuration R

The T34D payload separation shock environment requirement at the IUS interface is defined by Figure 2.1.1-1. Reference 5.9 contains test results showing that this requirement is exceeded between 280 Hz and 670 Hz as shown in Figure 3.1.1-1. The Payload Fairing Separation Shock environment is significant only for components located aft of the Stage I motor (see Section 2.3.3.2). Only two components are located aft of the Stage I motor, the separation connector and the pyro-connector. Figures 3.1.1-2 and 3.1.1-3 are comparisons of the pyroshock CQT requirements for these components with the measured payload fairing separation shock environment. These comparisons show a greater than 6 dB margin between environment and CQT requirement with one exception, 2.7 dB at 400 Hz for the pyro-connector. However, the pyro-connector is qualified with a 6 dB margin over the Prime Item Specification requirement criteria for payload fairing separation (Figure 2.1.1-1). Thus, the T34D configuration IUS vehicle is qualified for the Reference 5.2 specified payload fairing separation shock environment.

3.1.1.2 TITAN 4 Configuration

An evaluation of the TITAN 4 payload fairing separation shock is provided in reference 5.22. The evaluation shows that the IUS is compatible with the TITAN 4 induced shock. A copy of reference 5.22 is presented in Volume 3. A

3.1.2 Super*Zip Separation Shock

3.1.2.1 T34D Configuration

The IUS vehicle is separated from the T34D booster with a Super*Zip separation joint attached to the Stage I motor aft skirt. The three separation connectors and the pyro-connector have demonstrated satisfactory separation during the Super*Zip shock event as documented in the Reference 5.10 pyroshock/separation test. The nearest components to the Super*Zip which must function after separation are the Stage I FTS components located on the Stage I motor case (the TIU, two destruct batteries and the Safe and Arm Device).

Figure 3.1.2.1-1 shows the shock environment measured on the motor case representative of the input shock environment to the Stage I FTS system support structure. As indicated in Reference 5.8, the mass loading flexibility and structural dispersion effects of the FTS support structure will reduce the Figure 3.1.2.1-1 shock environment. An estimate of the shock environment experienced by the FTS components is shown in Figure 3.1.2.1-2, considering conservatively only the structural dispersion. Figure 3.1.2.1-3 compares the pyroshock CQT requirements for the FTS components with the Super*Zip separation shock environment showing a greater than 6 dB margin. Thus, based on the component qualification testing and the Reference 5.10 separation subsystem qualification test the T34D configuration IUS vehicle is qualified for the Super*Zip separation shock environment.

3.1.2.1 T34D Configuration (cont.)

Reference 5.23 contains TITAN T34D/IUS Super*Zip separation shock data from tests conducted in 1978. Although the reference 5.23 data are from the IUS DTV (Development Test Vehicle), the data provide information relative to shock dissipation through the structure. A summary of the data contained in reference 5.23 is presented in Volume 3. A

3.1.2.2 STS Configuration

The STS Configuration IUS vehicle configuration is equivalent to the T34D configuration from the Stage I motor aft except the STS configuration has no FTS system, or separation connectors. In addition, the STS configuration has one equipment item not located on the T34D configuration; a separation switch, used to indicate successful separation. As shown in paragraph 3.3.2 the separation switch is qualified with a 6 dB margin for the Super*Zip pyroshock environment. In all other respects the T34D configuration qualification rationale demonstrates the STS configuration adequacy. Successful performance of the STS Super*Zip separation was demonstrated during the ASE Super*Zip separation test (see paragraph 3.2.2).

3.1.3 Safe and Arm Device Shock

Each solid rocket motor is ignited through a pair of motor ignition Safe and Arm Devices. The SRM-1 motor S&A's are located on the interstage. The SRM-2 motor S&A's are located on a bracket mounted on the ESS skin near the S/C interface joint. The T34D configuration includes two additional S&A's for the FTS. Shock produced by these FTS S&A's is irrelevant since the vehicle is destroyed should these S&A's be fired. Both pairs of motor ignition S&A's are mounted on vibration isolators.

During the QTV pyroshock testing (see Reference 5.11 report) the SRM-2 ignition S&A's were fired and shock environments measured. Figure 3.1.3-1 is the source shock measured on the S&A. Figure 3.1.3-2 is the shock measured on the S&A support structure (after transmission through the vibration isolators).

The equipment items closest to the Safe and Arm Devices on the interstage are the Avionics Batteries. The components closest to the Safe and Arm in the ESS are the REM, and the Antennas. All of the components are tested to the 4000 g pyroshock CQT requirement (shown compared with the S&A environment on Figure 3.1.3-2). This comparison shows that the component CQT requirements provide more than a 6 dB margin over the Safe and Arm firing environment. Thus the IUS vehicle (both configurations) is qualified for the Safe and Arm firing pyroshock environment.

3.1.4 I/II Staging Explosive Nut Shock

Stage I/Stage II separation of the IUS vehicle is accomplished by explosive nuts at eight locations. To provide high reliability separation, two explosive nuts are used at each location (a single stud with a nut on both sides of the interface, illustrated on Figure 3.1.4-1). The separation sequence initiates the eight aft nuts followed 40 milliseconds later by initiation of the forward eight nuts. Thus, Stage I/Stage II separation produces two pyrotechnic shock events separated by 40 milliseconds.

3.1.4 I/II Staging Explosive Nut Shock (cont'd)

A I/II Staging Pyroshock/Separation test was conducted on the IUS-QTV (Reference 5.11). The shock environment produced by the explosive nuts was measured at two locations approximately four inches from the forward nut (Acc. Loc. 1 on the 292.5° longeron and Acc. Loc. 70 on the 67.5° longeron). Figures 3.1.4-2 through 3.1.4-8 show the source shock on the 292.5° longeron. Figures 3.1.4-9 through 3.1.4-15 show the source shock on the 67.5° longeron.

Two additional pyroshock separation tests of the I/II staging event were conducted to provide an improved statistical base for measurement of the S/C interface shock environment, Reference 5.16. A copy of Reference 5.16 is in Volume 3. Reference 5.16 R also contains an evaluation of shock reduction techniques.

The IUS vehicle is qualified for the I/II Staging shock by pyroshock CQT testing conducted on individual components. Component shock environments were measured during the IUS-QTV pyroshock/separation test. The Reference 5.11 contains an evaluation of this data showing that the component pyroshock CQT testing covers, with the MIL-STD-1540 required margin, the I/II staging pyroshock environment for all components except the RF Switch and the ESS TIU. The TIU, unique to the T34D configuration ESS, was not included in the QTV. The RF Switch was retested to increased CQT requirements (Figure 2.2.2-4). The TIU was tested to the Figure 2.2.2-2 pyroshock CQT requirement successfully. Analyses showing adequacy of the Pyroshock CQT requirements for the TIU and the revised requirements for the RF Switch are shown in paragraph 3.3.2.

In 1984 testing was conducted to determine the effect of simultaneous separation nut firing. Pyrotechnic shock measurements obtained during the test showed that the shock spectra were not significantly changed. The data are presented in reference 5.24. A copy of reference 5.24 is presented in Volume 3. A

The separation nuts were modified by removing a retainer ring. Pyrotechnic shock measurements on nuts with and without the retainer ring were obtained. Shock spectra from these measurements show that the shock induced by the nut firing is not significantly changed by the modification. Reference 5.25 contains the shock data. An edited copy of reference 5.25 is presented in Volume 3.

3.1.5 Spacecraft Induced Pyroshock Environment

3.1.5.1 Analysis

The IUS vehicle must demonstrate with a 6 dB margin a capability to experience S/C induced pyroshock events, as defined in paragraph 2.1.3. The IUS program development plan required demonstration of this capability by analysis, since test data relating IUS component environments due to spacecraft induced pyroshock events is usually not available. An analytical method of predicting component environments using data measured during the IUS QTV I/II staging pyroshock test has been developed. This method consisted of developing a transfer function between the S/C interface and components by combining individual transfer function between S/C interface separation nut source and components. The QTV shock data was placed in the STS interactive graphics VAX 11/780 computer to facilitate the large amount of calculation required. Figure 2.3.3.3-1 is a flow diagram illustrating this calculation process in the computer. The results of these calculations and the evaluation of IUS equipment compatibility with spacecraft generated shock as defined in paragraph 2.1.3 are presented in Appendix C.

3.1.5.1 Analysis (cont'd)

Separate analyses have been conducted for individual payloads as shown in the following:

Appendix B - DSCS
Appendix A - TDRS
Appendix D - DSP

Conclusions and recommendations relative to each spacecraft shock analysis are contained in the appropriate appendix.

3.1.5.2 Test

Shock measurements due to DSP 14 spacecraft induced pyrotechnic shock were obtained on the IUS. The shock was caused by activation of the DSP separation devices. Both test and analyses were required to show that IUS components are compatible with the DSP induced shock. Reference 5.26 contains the test and analysis results. A copy of reference 5.26 is in Volume 3. A

3.1.6 Umbilical Release Pin Puller Shock

Accelerometer measurements on the simulated IUS vehicle were recorded during the ASE functional test umbilical release, Reference 5.27. These data are shown on Figures 3.1.6-1 through 3.1.6-6. The complete set of data is presented in Reference 5.28. A copy of Reference 5.28 is in Volume 3. These measurements are representative of the environment experienced at the IUS trunnion ring umbilical clamp point. The only item of equipment located closer to this point than to a Stage I/II separation nut is the REM (N37). As shown in Figure 3.1.6-7 the REM CQT requirements far exceed the umbilical pin puller shock environment even if no shock attenuation were experienced. A comparison of the umbilical pin puller shock with the separation nut shock is shown in Figure 3.1.6-8. All IUS equipment has demonstrated a capability for the separation nut shock (paragraph 3.3.2), which is much more severe than the umbilical pin puller shock. Thus, it is concluded that all IUS equipment items are satisfactorily qualified for the environment resulting from umbilical release pin puller shock. R

3.2 ASE Qualification

The ASE, is located in three areas of the STS Orbiter: (1) the Aft Flight deck of the crew compartment;(2) Fwd ASE in the payload bay and (3) Aft ASE in the payload bay. Only the Aft ASE in the payload bay will experience a pyroshock environment. Two events produce significant pyroshock environments on the aft ASE; AFTA pin puller operation and Super*Zip separation joint activation. R

3.2.1 Pin Puller Shock

After STS Orbiter boost and in preparation for launch the IUS is titled up from a horizontal payload bay to a position 58° from horizontal. This event is accomplished with the Aft Frame Tilt Actuator (AFTA) attached to a slip ring on the aft ASE. A pin puller is used for the AFTA to slip ring attachment to allow release of the AFTA in the event of a hang up. In this case, the IUS would then be rotated into position by a backup AFTA.

During the ASE functional test (Reference 5.27) the AFTA pin puller was fired four (4) times. Three (3) pin puller firings were made with no load applied by the AFTA. A fourth firing was conducted with an 83 pound load applied by the AFTA. Accelerometer measurements of the pyroshock environment resulting from pin puller activation were obtained on the AFTA and adjacent components. The shock spectra from the measurements are presented in Reference 5.28. A copy of Reference 5.28 is in Volume 3. These data are used in paragraph 3.3.2 to show that the ASE is qualified for the pin puller pyroshock environment by CQT testing conducted on individual components. R

3.2.2 Super*Zip Shock

During an STS boost the IUS vehicle is separated from the orbiter/ASE with a Super*Zip separation joint attached to the Stage I motor aft skirt. A pyroshock/separation test was conducted on the ASE (Reference 5.17). Shock environments were measured on the ASE components and the Stage I motor aft skirt. These data are used in paragraph 3.3.2 to show IUS vehicle and ASE qualification by pyroshock CQT testing conducted on individual components.

The Super*Zip separation system includes a second redundant ordnance train capable of separating the interface should the primary system fail. During the ASE pyroshock qualification test this redundant Super*Zip ordnance was detonated and component shock environments measured. As shown in reference 5.17 the redundant Super*Zip shock, although significant, was less severe than the primary Super*Zip shock environment.

3.3 IUS Component Qualification

3.3.1 Transportation and Handling Shock

Component qualification for the transportation and handling shock requirement (paragraph 2.2.1) is demonstrated by analysis or test as specified in the individual component CI specification or envelope drawing. The analysis showing qualification for the transportation and handling shock requirement is documented in the individual component qualification test reports.

3.3.2 IUS Generated Pyroshock Environments

Three IUS system events produce a significant pyroshock for IUS components; (1) Super*Zip separation, (2) pin pullers and (3) explosive nut I/II Stage separation. Table 3.3.2-A contains a list of all IUS system components and indicates the method and reference showing qualification adequacy.

Reference 5.11 contains test data measured during the IUS-QTV pyroshock/separation test showing that all CQT pyroshock testing covers with a 6 dB margin the explosive nut separation shock environment except for the RF Switch, the TIU and the SCU and WBDI code plugs (these items are discussed in the following paragraphs). Certain items within the QTV were not instrumented but as shown in Table 3.3.2-B are covered by measurements on representative components or structure. Comparisons of the component CQT requirements with the environments measured during the QTV I/II staging pyroshock tests are shown in Vol. II of this document.

Reference 5.17 contains test data measured during the ASE Super*Zip pyroshock separation test showing that all component CQT pyroshock testing covers with at least a 6 dB margin the ASE Super*Zip separation shock environment.

Comparisons of the component CQT requirements with the environments measured during the ASE Super*Zip pyroshock tests are shown in Reference 5.17. Reference 5.15 contains R data showing that T34D/IUS separation subsystem is qualified for the T34D Super*Zip separation shock environment.

ASE pin puller shock environments on components near the source were measured during the ASE functional test. These data including a comparison of the adjacent component CQT R requirements with the pin puller shock environment are shown in Reference 5.28. A copy of Reference 5.28 is in Volume 3.

3.3.2.1 RF Switch Pyroshock CQT Requirement

Figures 3.3.2.1-1 through 3.3.2.1-18 show shock spectra of shock measured at the RF Switch attachment structure during the three IUS-QTV explosive nut I/II Staging pyroshock separation tests. The mean and envelope spectra for each axis are shown in Figures 3.3.2.1-19 through 3.3.2.1-21. Figures 3.3.2.1-22 through 3.3.2.1-24 are a comparison of the revised pyroshock CQT requirements with the I/II Staging P95/50 shock environment. The RF Switch has successfully passed the requalification to the revised pyroshock CQT requirements as documented in Reference 5.12.

3.3.2.2 ESS TIU Pyroshock CQT Requirement

The ESS TIU is located at approximately 45° on the T34D configuration ESS deck. The TIU is mounted on Vibration Isolators.

During the IUS-QTV explosive nut pyroshock/separation tests (Reference 5.11) a utility battery was located on the deck in the position that the TIU occupies in the T34D configuration. Shock response in the axial axis was measured on the structure near the battery attachment location. Figure 3.3.2.2-1 is an envelope of these measurements from all three pyroshock/separation tests.

The TIU vibration isolators dynamic characteristics were measured during the IUS-2 (T34D Configuration) acoustic acceptance test, Reference 5.13. Figures 3.3.2.2-2 through 3.3.2.2-4 are vibration transfer functions for the TIU installation. The transfer functions were calculated using the program described in paragraph 2.3.4 from vibration PSD measurements on both sides of the vibration isolators.

Estimates of the TIU pyroshock environment resulting from I/II Staging explosive nut initiation are based on data measured on the vibration isolated PDU during the IUS-QTV pyroshock test (Reference 5.11). Figure 3.3.2.2-5 compares the axial shock input at the PDU attachment with the axial axis measurement of shock measured on the battery support structure at the TIU location. This comparison shows that the shock environment input to the PDU was more severe than that at the TIU location.

Figures 3.3.2.2-6 and 3.3.2.2-7 are transfer function plots (based on Reference 5.14) of the PDU installation showing first mode frequencies and attenuation characteristics similar to the TIU. It is assumed that the PDU environment represents a conservative estimate of TIU shock since the PDU input shock levels are more severe and the

dynamic characteristics are similar. The shock input and response shock spectra measured on the PDU installation in the axial and radial axes are shown on Figures 3.3.2.2-8 and 3.3.2.2-9. (No input shock was measured in the tangential axis). Shock spectra of the tangential axis response is shown in Figure 3.3.2.2-10. No input shock was measured in the tangential axis.

Figure 3.3.2.2-11 compares an envelope of all PDU response shock spectra with the TIU pyroshock CQT requirements. This comparisons show a greater than 6 dB margin. Therefore, the TIU CQT requirements are adequate to qualify the TIU for the I/II Staging explosive nut shock environment.

3.3.2.3 Code Plug, SCU and Code Plug, WBDI

The SCU and WBDI code plugs are connectors with jump wires between specific pins. The code plugs are not used during component level CQT testing since the component must interface with the STE. Since the code plug contains no electronics it is reasonable to demonstrate qualification in the same fashion as the vehicle and ASE wiring at the system level. Both the SCU and WBDI code plugs were installed during system level pyroshock testing.

3.3.2.4 Separation Nuts

During the QTV pyroshock separation tests, 24 separation nuts (8 nuts X 3 separations) functioned satisfactorily after experiencing the shock created by separation of the aft nut from the same stud. This shock is significantly greater than the shock the nuts will experience if the redundant performance is required, i.e. the shock created by explosive nuts on adjacent longerons if the aft nut does not separate.

4.0 Shock Environment Interface Analyses

4.1 T34D/IUS Separation Shock Environment on the T34D

Per Reference 5.2, the maximum shock allowable at the T34D/IUS interface resulting from T34D/IUS separation is defined by the Figure 4.1-1 shock spectrum. Shock data was measured at the interface during the T34D/IUS separation subsystem pyroshock/separation qualification test (Reference 5.15). Figure 4.1-2 compares an envelope of shock spectra of measurements recorded at the T34D/IUS interface during the Reference 5.15 test with the Reference 5.2 allowable. This comparison shows that the T34D/IUS separation shock environment is within the allowable limits at the T34D/IUS interface. Thus the requirement of Figure 8B Paragraph 3.2.5.4.5 of Reference 5.2 is satisfied. These data are applicable to the T34D and TITAN 4. A

4.2 IUS/ASE Shock on the STS Orbiter

4.2.1 AFTA Pin puller Shock

Figures 4.2.1-1 through 4.2.1-6 are comparisons of the AFTA pin puller shock measured at the ASE/Orbiter interface with the Orbiter ICD (Reference 5.19) allowable limit shock. These comparisons show that the AFTA pin puller shock is within the required limit. See paragraph 4.4.

4.2.2 Super*Zip Shock

Figures 4.2.2-1 through 4.2.2-6 are comparisons of the super*zip shock measured at the ASE/Orbiter interface with the Orbiter ICD (Reference 5.19) allowable limit shock. These comparisons show that the super*zip shock is within the required limit. See paragraph 4.4.

4.3 IUS/Spacecraft Interface Shock Environment on the Spacecraft

Per Reference 5.1, the maximum shock allowable at the S/C interface resulting from IUS shock events is defined by the Figure 4.3-1 shock spectrum. The IUS vehicle contains three pyrotechnic devices, (1) Super*Zip Separation Joint (2) Safe and Arm Devices and (3) the I/II Staging Separation Nuts.

The Super*Zip separation joint is used to separate the IUS vehicle from the STS ASE or the TITAN booster. Shock produced by the Super*Zip separation will be attenuated to an insignificant level at the S/C interface by transmission across the Stage I motor, up the interstage and through the ESS structure. The shock level only 1/2 the distance across the Stage I motor is well below the S/C interface allowable shock as shown on the Figure 4.3-2 comparison.

The ESS Safe and Arm is located near the S/C interface joint. The shock environment produced by the Safe and Arm Device is attenuated significantly by the Safe and Arm vibration isolation support structure. Figure 4.3-3 compares the Safe and Arm shock environment on support structure with the S/C interface allowable shock. The comparison shows the S&A induced environment is less than the S/C allowable. R

The I/II Staging explosive nuts produce the most significant shock environment at the S/C interface. Three pyroshock/separation tests were conducted on the IUS-QTV (Reference 5.11, test report). Triaxial accelerometers were located at all eight S/C interface attachment locations. No S/C simulator was included in the test, i.e., the interface was free. Reference 5.11 contains a discussion of this test and a statistical evaluation of the S/C interface shock environment. The statistical evaluation was conducted using the program described in paragraph 2.3.2. Figures 4.3-4 through 4.3-6 show a comparison of the mean and P95/50 levels of the S/C interface environment measured during the Reference 5.11 test with the S/C allowable shock environment. These comparisons show that the I/II Staging explosive nut shock is less than the S/C maximum allwable shock.

Shown in the above paragraphs all IUS shock events produce a shock environment at the S/C interface less than the Maximum Allowable. Thus, the requirement of paragraph 3.2.5.5.2 of Reference 5.1 is satisfied.

4.4 Revised Shock environment, ASE/Orbiter

Interface Revision Notice 286 to ICD 2-19001 defines revised shock environments between ASE and the Orbiter, reference 5.20. An analysis was conducted to evaluate compatibility between ASE and Orbiter in the revised environments, reference 5.21. The analysis shows that the ASE and Orbiter are compatible. The analysis is presented in Appendix E.

5.0 References

5.1 S290-70001 Rev. A, "Prime Item Development Specification for DOD Two-Stage Vehicle Inertial Upper Stage CI 290007A", 12 June 1981.

5.2 S290-70001-4 Rev. A, "Addendum Specification for Titan Two-Stage Vehicle Inertial Upper Stage CI 290046A", 12 June 1981.

5.3 MIL-STD-1540A (USAF), "Test Requirements for Space Vehicles", 15 May 1974.

5.4 Test Progress Report 2-5693-7800-016, "IUS Separation Test – Pyrotechnic Shock", 26 January 1978.

5.5 Test Progress Report 2-5693-7900-022, "IUS Aft ASE Separation Test", 8 February 1979.

5.6 D290-75308-2, "IUS Shock, Vibration and Acoustics Data and Analysis Procedures". 9 May 1983.

5.7 Harris, C. M. and C. E. Crede, "Shock and Vibration Handbook 2nd Edition", 1976, McGraw-Hill, Inc., Chapter 23.

5.8 MCR-69-611, "Aerospace Systems Pyrotechnic Shock Data", NASA Contract NAS55-15208, 7 March 1970.

5.9 MCR-79-089, "Titan 34D Payload Fairing Separation Test Report of High Frequency Shock Response Data", September 1979.

5.10 22T2-002A, "T34D/IUS Separation Subsystem Acoustic and Pyroshock/Separation Test Report", 30 January 1981.

5.11 22B5-005R, "Pyroshock-Staging/Separation QTV, Final Test Report", 1 December 1981.

5.12 Fail Safe Switch QTR 2352, Rev. A., 30 November 1981.
Latching Switch QTR 2362, Rev. A., 30 November 1981.

5.13 D290-10818-1, "IUS-2 Acceptance Test Report", Released 23 November 1981.

5.14 22B5-007R, "Test Report, Qualification Test Vehicle Acoustic Test". Released 1 October 1981.

5.15 Same as Reference 5.10

5.16 Boeing Memo 2-3612-IUS-445, Special Study FSD-81-003, IUS Pyrotechnic Shock Reduction, Stage I/II Separation", dated 29 July 1981. R

5.17 22B5-018R, "ASE Pyroshock Separation Test Qualification", revision A, 5 Nov 1982. R

5.18 D290-10868-1, "QL-1 Drop Test Report, SRM-1, FSD Program", to be released.

5.19 ICD-D-E0001, "Shuttle Orbiter/Inertial Upper Stage Cargo Element Interfaces", dated 6/29/78.

5.20 Interface Revision Notice (IRN) 286 to ICD 2-19001 (Shuttle Orbiter/Cargo Element Interfaces), title, Add Updated Environments and Update of Entire Appendix 1, dated 15 October 1987.

5.21 Boeing Memo 2-3612-IUS-087/88, to W. Benshoof from W. Gustafson, subject, Vibration and Shock Environment Evaluation, IRN 286 to ICD 2-19001, Revision A, 12 May 1988.

5.22 Boeing Memo 2-3612-IUS-058/88, "TITAN 4 Payload Fairing Shock Data, ECP 2246", revision A, 7 July 1988. A

5.23 Test Progress Report 2-5693-7800-117, "TITAN/IUS (T34D/DTV) Separation Shock Test", 3 January 1979. A

5.24 Boeing Memo-2-3612-IUS-020/84, Evaluation of Pyrotechnic Shock Data", 31 January 1984. A

5.25 Boeing Memo 2-3612-IUS-249/88, "Results of Separation Nut Vibration and Shock Testing", 22 December 1988. A

5.26 Boeing Memo 2-3612-IUS-014/86, "DSP/IUS Shock Evaluation," 18 March 1986. A

5.27 Boeing Test Report 22B5-038R, "ASE Mechanical Functional Test - Post Environment", 7 October 1982. A

5.28 Boeing Memo 2-3612-IUS-716, "ASE AFTA and Umbilical Pin Puller Shock Test", 7 October 1982. A

5.29 Boeing Document D290-75303-1, "IUS Program Vibration Analysis/Flight Data", Volume 4, 9 December 1991. A

6.0 Flight Data

Shock data have been obtained during launch and flight of the IUS. An analysis of shock data from the TITAN/IUS and STS/IUS flights is presented in Reference 5.29. A

Table 2.2.2-A
PYROSHOCK CQT REQUIREMENTS

Component	Pyroshock CQT Requirement
Avionics Battery	Figure 2.2.2-1
AFTA	Figure 2.2.2-1
ASE DC/DC Converter	Figure 2.2.2-1
AFTA Controller	Figure 2.2.2-1
Computer	Figure 2.2.2-3
ESS DC/DC Converter	Figure 2.2.2-1
DC Block	Figure 2.2.2-1
Destruct Battery	Figure 2.2.2-1
EMU	Figure 2.2.2-1
Separation Connector	Figure 2.2.2-8
IDA	Figure 2.2.2-1
Medium Gain Antenna	Figure 2.2.2-1
Omni Antenna	Figure 2.2.2-1
PCU	Figure 2.2.2-2
PDU	Figure 2.2.2-2
PSU	Figure 2.2.2-1
PTU	Figure 2.2.2-1
20 Watt Power Amplifier	Figure 2.2.2-1
Pyro Connector	Figure 2.2.2-9
RCS Tank	Figure 2.2.2-1
REM	Figure 2.2.2-1
RF Switch	Figure 2.2.2-4
RIMU	Figure 2.2.2-1
Safe and Arm Device	Figure 2.2.2-2
SCU	Figure 2.2.2-7
Separation Switch	Figure 2.2.2-5
SGLS Transponder	Figure 2.2.2-1
SIU	Figure 2.2.2-6
TIU	Figure 2.2.2-2
TVC Actuator	Figure 2.2.2-1
TVC Potentiometer	Figure 2.2.2-1
TVC Controller	Figure 2.2.2-1
Utility Battery	Figure 2.2.2-1
WBDI	Figure 2.2.2-2
Pin Puller	Figure 2.2.2-1

Table 3.3.2-A

IUS Generated Pyroshock Component Compatibility Summary

COMPONENT NAME	BAC DWG. NUMBER	USED ON			QUALIFICATION COMPATIBILITY METHOD		
		T34D	STS	ASE	SUPER*ZIP	PIN PULLER	EXPLOSIVE NUT
SRM-1	290-21000	●	●	-	A (5.18)	N/A	N/A
SRM-2	290-21001	●	●	-	N/A	N/A	N/A
EEC Subsystem	CSD P/N B14661-21-01	●	●	-	N/A	N/A	N/A
REM	290-21005	●	●	-	N/A	N/A	R-CQT (5.11)
Safe & Arm	290-21005						
SRM-1 Ignition		●	●	-	N/A	N/A	N/A
SRM-2 Ignition		●	●	-	N/A	N/A	CQT (5.11)
SRM-1 FTS		●	-	-	N/A	N/A	N/A
SRM-2 FTS		●	-	-	N/A	N/A	R-CQT (5.11)
RCS Tank Assembly	290-21007	●	●	-	N/A	N/A	CQT (5.11)
RCS Manifold	290-21031	●	●	-	N/A	N/A	CQT (5.11)
Resistor Board Assembly	290-21066	●	●	-	N/A	N/A	R-CQT (5.11)

CQT - CQT covers with 6dB margin based on Ref( ) test results.
R-CQT - CQT covers with 6dB margin based on Ref( ) test results measured on a representative component per Table 3.3.2-B.
N/A - No significant Pyroshock environment exists.

A - Analysis Per Ref( ).

QTV - Qualification by three firings of explosive nuts per MIL-STD-1540 Paragraph 6.2.5.3

NR - Qualification for Pyroshock Per MIL-STD-1540A is optional.

Table 3.3.2-A (Cont.)

IUS Generated Pyroshock Component Compatibility Summary

COMPONENT NAME	BAC DWG. NUMBER	USED ON			QUALIFICATION COMPATIBILITY METHOD		
		T34D	STS	ASE	SUPER*ZIP	PIN PULLER	EXPLOSIVE NUT
Star Scanner	290-22127	-	●	-	N/A	N/A	CQT (5.11)
Inertial Measurement Unit (WBDI)	290-22118	●	●	-	N/A	N/A	CQT (5.11)
TVC Controller	290-22116	●	●	-	N/A	N/A	R-CQT (5.11)
TVC Actuator	290-22116	●	●	-	N/A*	N/A*	N/A*
TVC Potentiometer	290-22116	●	●	-	N/A*	N/A*	N/A*
Computer	290-22119	●	●	-	N/A	N/A	CQT (5.11)
SCU	290-26016	●	●	-	N/A	N/A	CQT (5.11)
Code Plug, SCU	290-26100	●	●	-	N/A	N/A	QTV (3.3.2.3)
SIU	290-26199	●	●	-	N/A	N/A	CQT (5.11)
TIU	290-26197						
SRM-1 FTS		●	-	-	N/A	N/A	N/A
SRM-2		●	-	-	N/A	N/A	A (3.3.2.2)

CQT - CQT covers with 6dB margin based on Ref( ) test results.
R-CQT - CQT covers with 6dB margin based on Ref( ) test results measured on a representative component per Table 3.3.2-B.
N/A - No significant Pyroshock environment exists.

A - Analysis Per Ref( ).

QTV - Qualification by three firings of explosive nuts per MIL-STD-1540 Paragraph 6.2.5.3

NR - Qualification for Pyroshock Per MIL-STD-1540A is optional.

* Pyroshock CQT was conducted per Table 2.2.2-A although the component does not experience any significant pyroshock environment.

Table 3.3.2-A (Cont.)

IUS Generated Pyroshock Component Compatibility Summary

COMPONENT NAME	BAC DWG. NUMBER	USED ON			QUALIFICATION COMPATIBILITY METHOD		
		T34D	STS	ASE	SUPER*ZIP	PIN PULLER	EXPLOSIVE NUT
RF Switch (2 Pole)	280-41008	●	●	-	N/A	N/A	CQT/A (3.3.2.1)
RF Switch (Fail Safe Relay)	280-41009	●	-	-	N/A	N/A	CQT/A (3.3.2.1)
Diplexer	290-22200	●	●	-	N/A	N/A	R-CQT (5.11)
Antenna, Omni	290-27105	-	●	-	N/A	N/A	NR, QTV [1]
Antenna, Medium Gain	290-27106	●	●	-	N/A	N/A	NR, QTV [1]
SGLS Transponder	290-22121	●	●	-	N/A	N/A	CQT, R-CQT (5.11)
20ω Power Amplifier	290-22117	●	●	-	N/A	N/A	CQT (5.11)
Coax. Cable Set	290-27435	●	●	-	N/A	N/A	QTV
EMU	290-22224	●	●	-	N/A	N/A	R-CQT (5.11)
EMU Transducers	290-22228	●	●	-	N/A	N/A	R-CQT (5.11)
DC Block	280-61001	●	-	-	N/A	N/A	N/A*

CQT - CQT covers with 6dB margin based on Ref( ) test results.
R-CQT - CQT covers with 6dB margin based on Ref( ) test results measured on a representative component per Table 3.3.2-B.
N/A - No significant Pyroshock environment exists.
A - Analysis Per Ref( ).
QTV - Qualification by three firings of explosive nuts per MIL-STD-1540 Paragraph 6.2.5.3
NR - Qualification for Pyroshock Per MIL-STD-1540A is optional.

* Pyroshock CQT was conducted per Table 2.2.2-A although the component does not experiency any significant pyroshock environment.

[1] Pyroshock CQT test were conducted per Table 2.2.2-A.

Table 3.3.2-A (Cont.)

IUS Generated Pyroshock Component Compatibility Summary

COMPONENT NAME	BAC DWG. NUMBER	USED ON			QUALIFICATION COMPATIBILITY METHOD		
		T34D	STS	ASE	SUPER*ZIP	PIN PULLER	EXPLOSIVE NUT
Utility Battery	290-61001	●	●	-	N/A	N/A	CQT (5.11)
Avionics Battery	290-22211						
Stage I		●	●	-	N/A	N/A	N/A*
STS ASE		-	-	●	N/A*, CQT (5.17)	N/A	N/A
Staging Connector	280-33019	●	●	-	CQT (5.15)	N/A	CQT (5.11)
Pyro Connector	280-33027	●	●	-	NR, T34D	N/A	N/A
Destruct Battery	290-27001	●	-	-	N/A*	N/A*	N/A*
Wiring Harness	290-27433	●	●	-	ASE	N/A	QTV
DC/DC Converter	290-22210	●	●	-	N/A	N/A	CQT (5.11)
PSU	290-26054	●	●	-	N/A	N/A	CQT (5.11)
PTU	290-27200	-	●	-	N/A	N/A	CQT (5.11)
PDU	290-26117	●	●	-	N/A	N/A	CQT (5.11)

CQT - CQT covers with 6dB margin based on Ref( ) test results.
R-CQT - CQT covers with 6dB margin based on Ref( ) test results measured on a representative component per Table 3.3.2-B.
N/A - No significant Pyroshock environment exists.
A - Analysis Per Ref( ).
QTV - Qualification by three firings of explosive nuts per MIL-STD-1540 Paragraph 6.2.5.3
NR - Qualification for Pyroshock Per MIL-STD-1540A is optional.
ASE - Functioned satisfactorally during the ASE Super*Zip separation test.
T34D - Functioned satisfactorally during the T34D Separation Subsystem Super*Zip separation test.
* Pyroshock CQT was conducted per Table 2.2.2-A although the component does not experience any significant pyroshock environment.

Table 3.3.2-A (Cont.)

IUS Generated Pyroshock Component Compatibility Summary

COMPONENT NAME	BAC DWG. NUMBER	USED ON			QUALIFICATION COMPATIBILITY METHOD		
		T34D	STS	ASE	SUPER*ZIP	PIN PULLER	EXPLOSIVE NUT
Isolation Diode Assembly	290-26070	●	●	-	N/A	N/A	R-CQT (5.11)
Temperature Sensor Assembly	290-26222	●	●	-	N/A	N/A	QTV, CQT (5.11)
Separation Nuts	290-24130	●	●	-	N/A	N/A	QTV (3.3.2.4)
Staging Mech. (SUPER*ZIP)	290-24006	●	●	●	N/A	N/A	N/A
Destruct Sys. Ordnance	290-24172	●	-	-	N/A	N/A	R-CQT (5.11)
PRLA	V073-544550 -003, 004	-	-	●	N/A	N/A	N/A
Load Leveler Actuator	290-30301	-	-	●	N/A	N/A	N/A
Accumulator	290-30304	-	-	●	N/A	N/A	N/A
Z Damper	290-30111	-	-	●	N/A	N/A	N/A
Umbilical Plug	288-33020	-	-	●	N/A	N/A	N/A
AFTA Actuator	290-30710	-	-	●	CQT (5.17)	CQT (3.2.2)	N/A

CQT - CQT covers with 6dB margin based on Ref( ) test results.
R-CQT - CQT covers with 6dB margin based on Ref( ) test results measured on a representative component per Table 3.3.2-B.
N/A - No significant Pyroshock environment exists.
A - Analysis Per Ref( ).
QTV - Qualification by three firings of explosive nuts per MIL-STD-1540 Paragraph 6.2.5.3
NR - Qualification for Pyroshock Per MIL-STD-1540A is optional.

Table 3.3.2-A (Cont.)

IUS Generated Pyroshock Component Compatibility Summary

COMPONENT NAME	BAC DWG. NUMBER	USED ON			QUALIFICATION COMPATIBILITY METHOD		
		T34D	STS	ASE	SUPER*ZIP	PIN PULLER	EXPLOSIVE NUT
AFTA Controller	290-30710	-	-	●	CQT (5.17)	CQT (3.2.2)	N/A
PCU	290-26004	-	-	●	CQT (5.17)	CQT (3.2.2)	N/A
WBDI	290-26102	-	-	●	CQT (5.17)	N/A (3.2.2)	N/A
DC/DC Converter	290-22210	-	-	●	CQT (5.17)	N/A (3.2.2)	N/A
Limit Switch	280-41012-101	-	-	●	CQT (5.17)	N/A (3.2.2)	N/A
Y Damper	290-30111	-	-	●	CQT (5.17)	N/A (3.2.2)	N/A
PCP	290-26006	-	-	●	N/A	N/A	N/A
Code Plug Assy. (WBDI)	290-26101	-	-	●	ASE (3.3.2.3)	N/A (3.2.2)	N/A
CIU	290-22235	-	-	●	N/A	N/A	N/A
Pin Pullers	290-22235	-	-	●	N/A*	N/A*	N/A*
Cable Assembly	290-27401	-	-	●	ASE	N/A (3.2.2)	N/A

CQT - CQT covers with 6dB margin based on Ref( ) test results.

R-CQT - CQT covers with 6dB margin based on Ref( ) test results measured on a representative component per Table 3.3.2-B.

N/A - No significant Pyroshock environment exists.

A - Analysis Per Ref( ).

QTV - Qualification by three firings of explosive nuts per MIL-STD-1540 Paragraph 6.2.5.3

NR - Qualification for Pyroshock Per MIL-STD-1540A is optional.

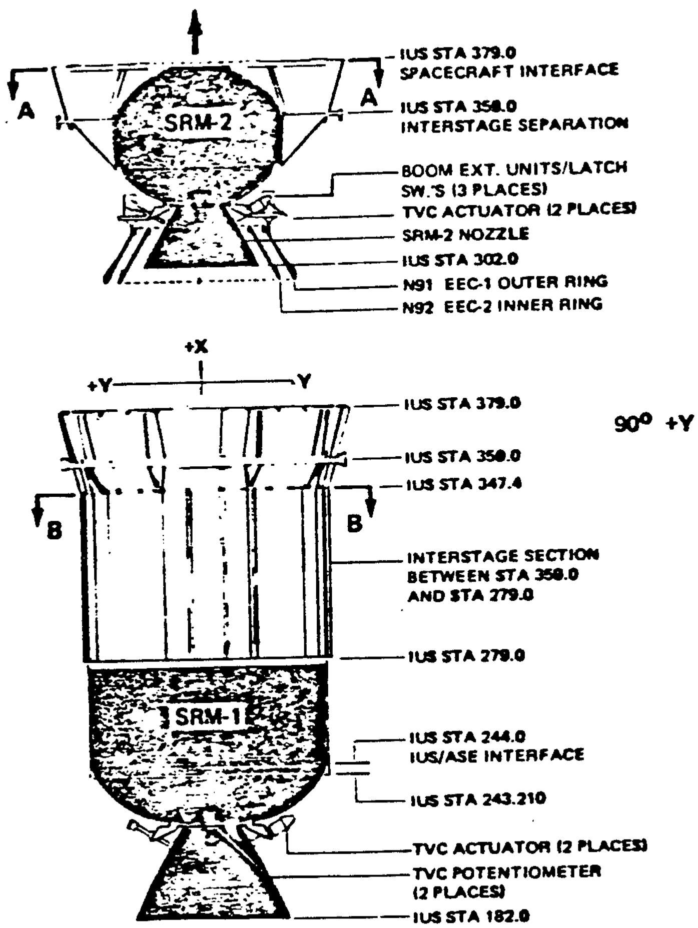
* Pyroshock CQT was conducted per Table 2.2.2-A although the component does not experiency any significant pyroshock environment.

Table 3.3.2-B

COMPONENT NAME	REPRESENTATIVE MEASUREMENT	
SRM-2 FTS S&A	SRM-2 Ignitor S&A	QTV Acc. 8A, R
Resistor Board Assy.	Isolation Valve Support Brkt. RF Switch Support Structure	QTV Acc. 16A, R, T QTV Acc. 44A, R, T
REMs @	REM @ 185°	QTV Acc. 4A, R, T
TVC Controller	Decryptor SIU Transponder B	QTV Acc. 18A, R, T QTV Acc. 15A, R, T QTV Acc. 10A, R, T
Diplexer	RF Switch Support Structure	QTV Acc. 44A, R, T
Transponder A	SIU Decryptor	QTV Acc. 15A, R, T QTV Acc. 18A, R, T
EMU	Decryptor	QTV Acc. 18A, R, T
EMU Transducers	S/C Interface Ring QTV Acc's	67A, R, T 63A, R, T 37A, R, T
Destruct System Ordnance	SRM-2 Ignition S&A	QTV Acc. 8A, R
Isolation Diode Assembly	Hard Mount Near PDU	QTV Acc. 13A, R

STAGE-2

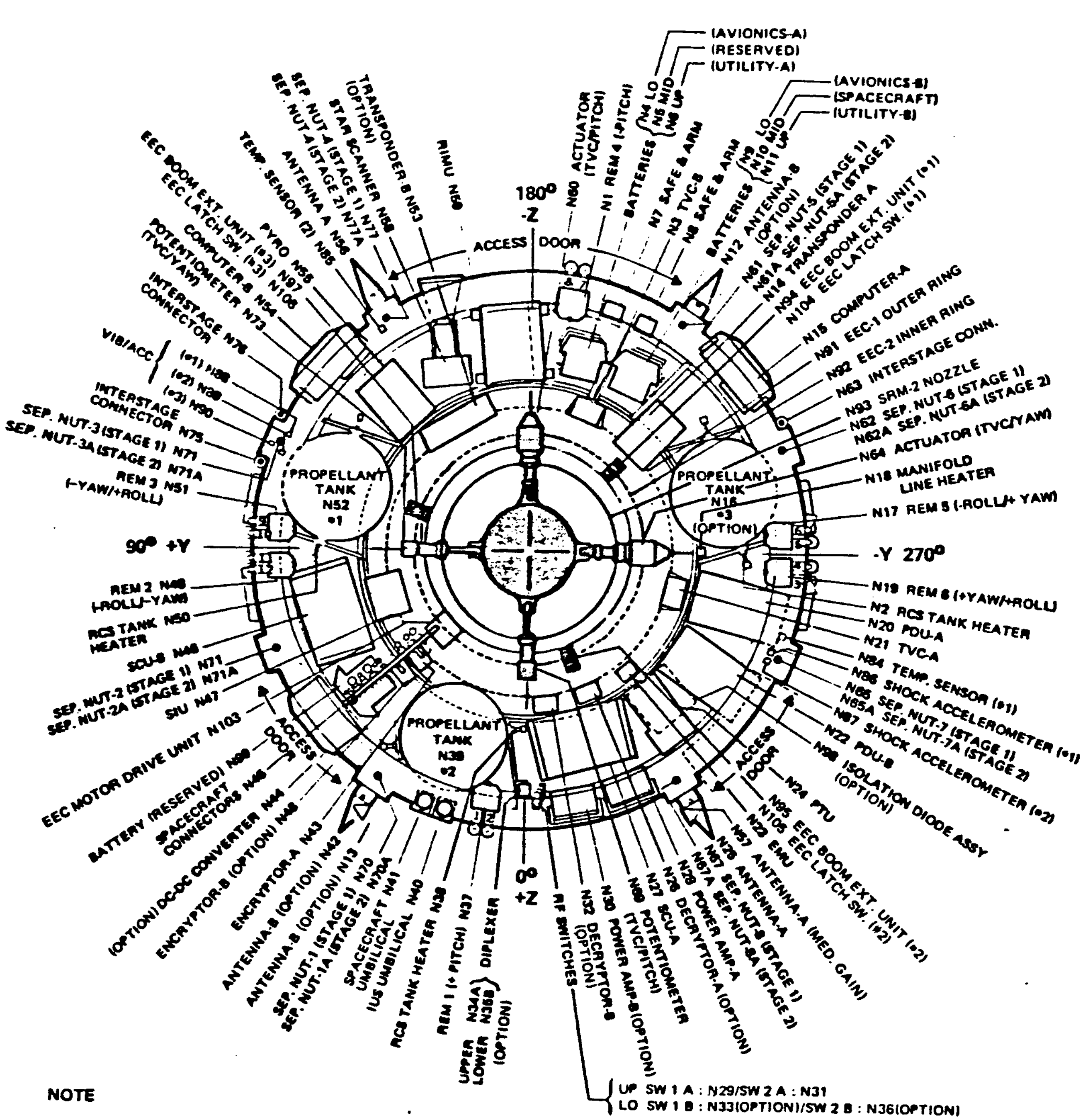
EQUIPMENT SUPPORT SECTION



STAGE-1

IUS SIDE VIEW PROJECTION
FACING AXIS +Y/-Y (AT 0°)

Figure 1.0-1 DOD-STS Configuration IUS Vehicle

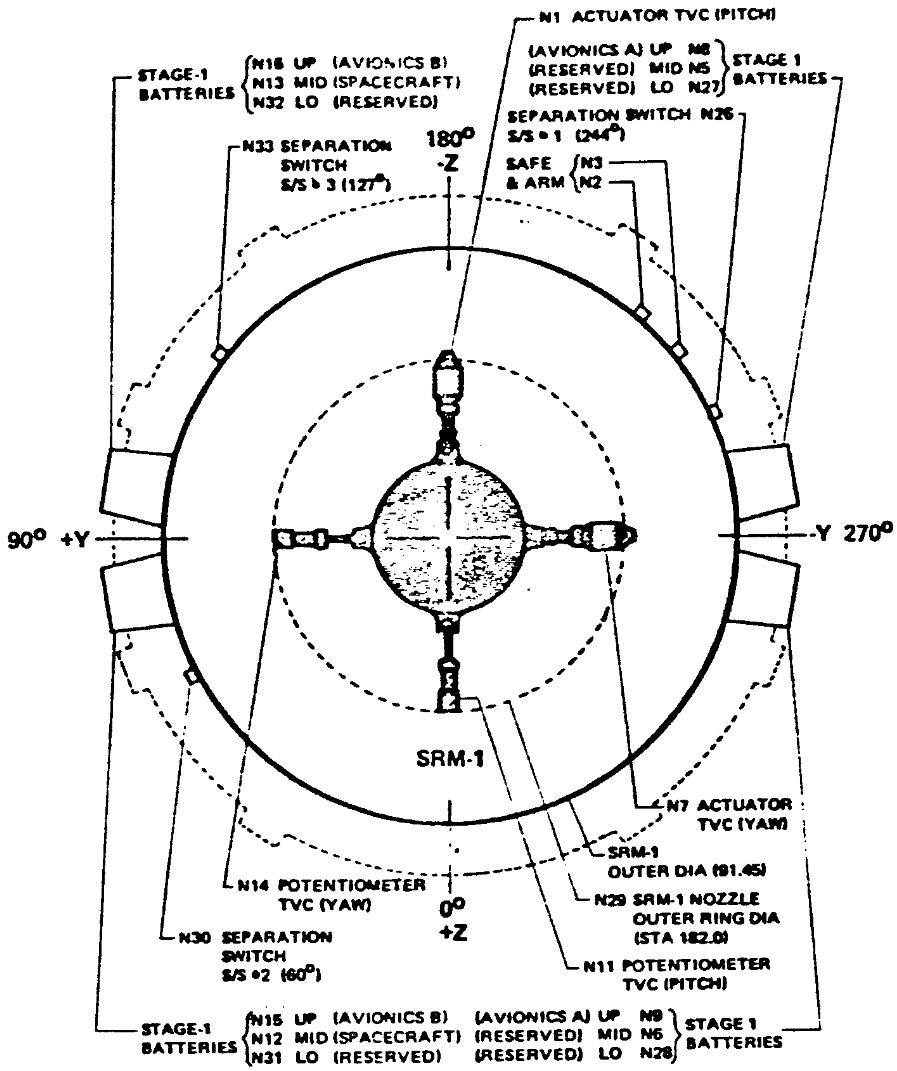


NOTE

COMPONENTS THAT ARE SHADED ARE LOCATED UNDER SRM.

VIEW A-A STAGE-2

Figure 1.0-2 Equipment Support Section (Avionics Bay) (STS)



VIEW B-B STAGE-1

Figure 1.0-3 IUS Vehicle Equipment Layout (STS)

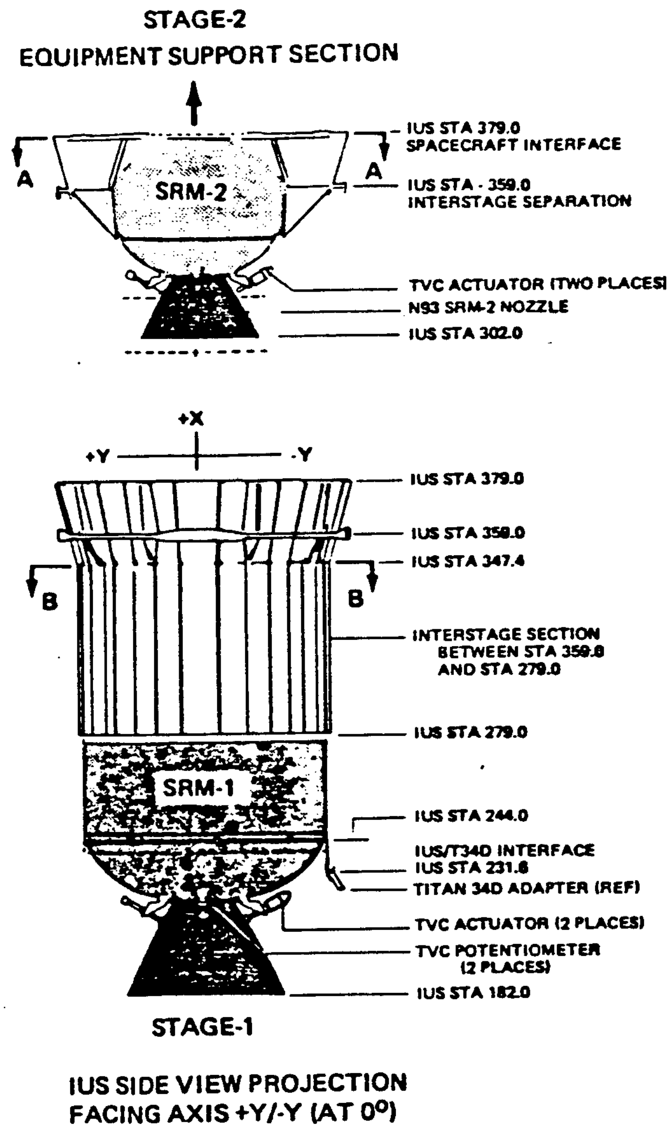
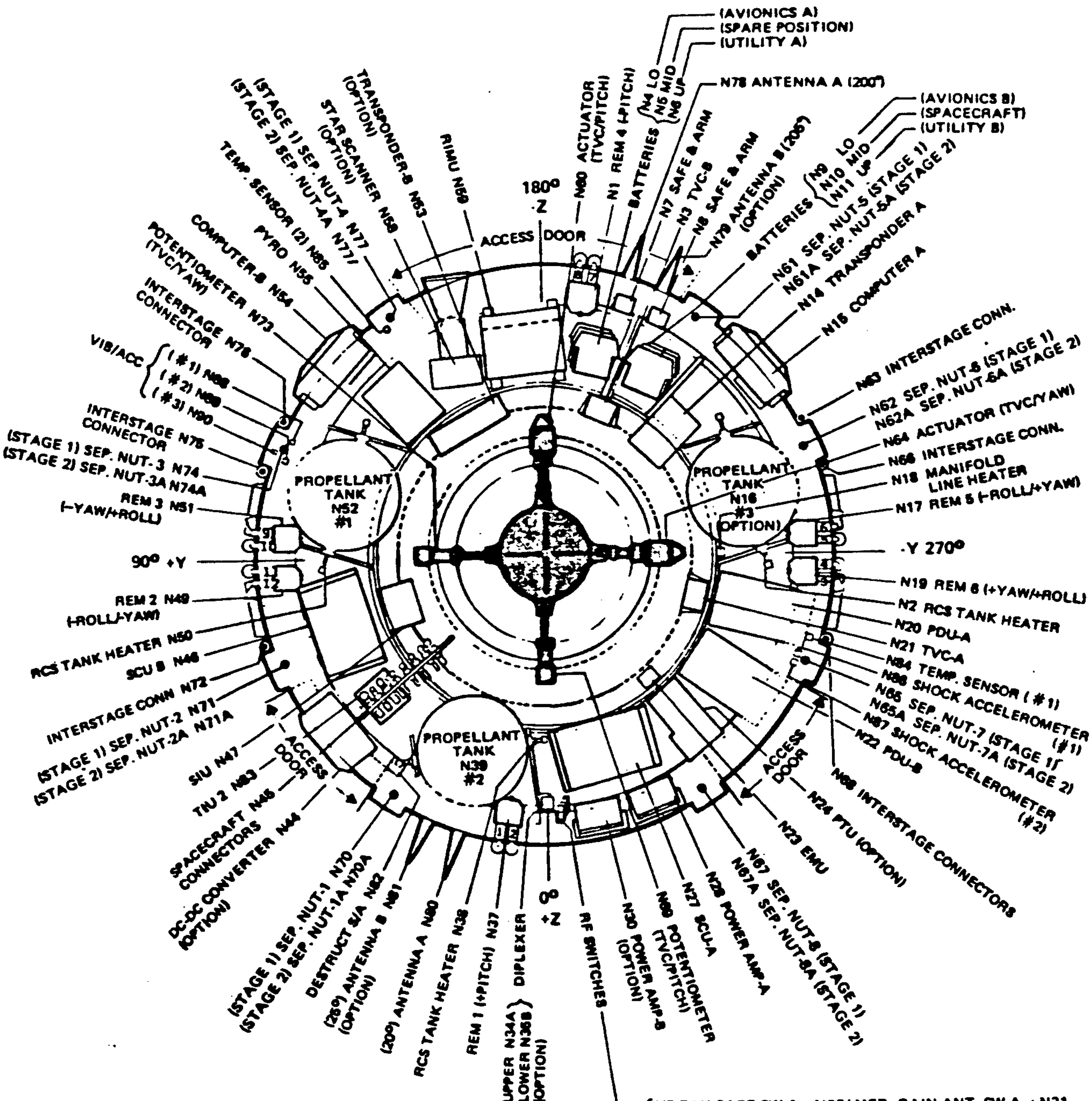


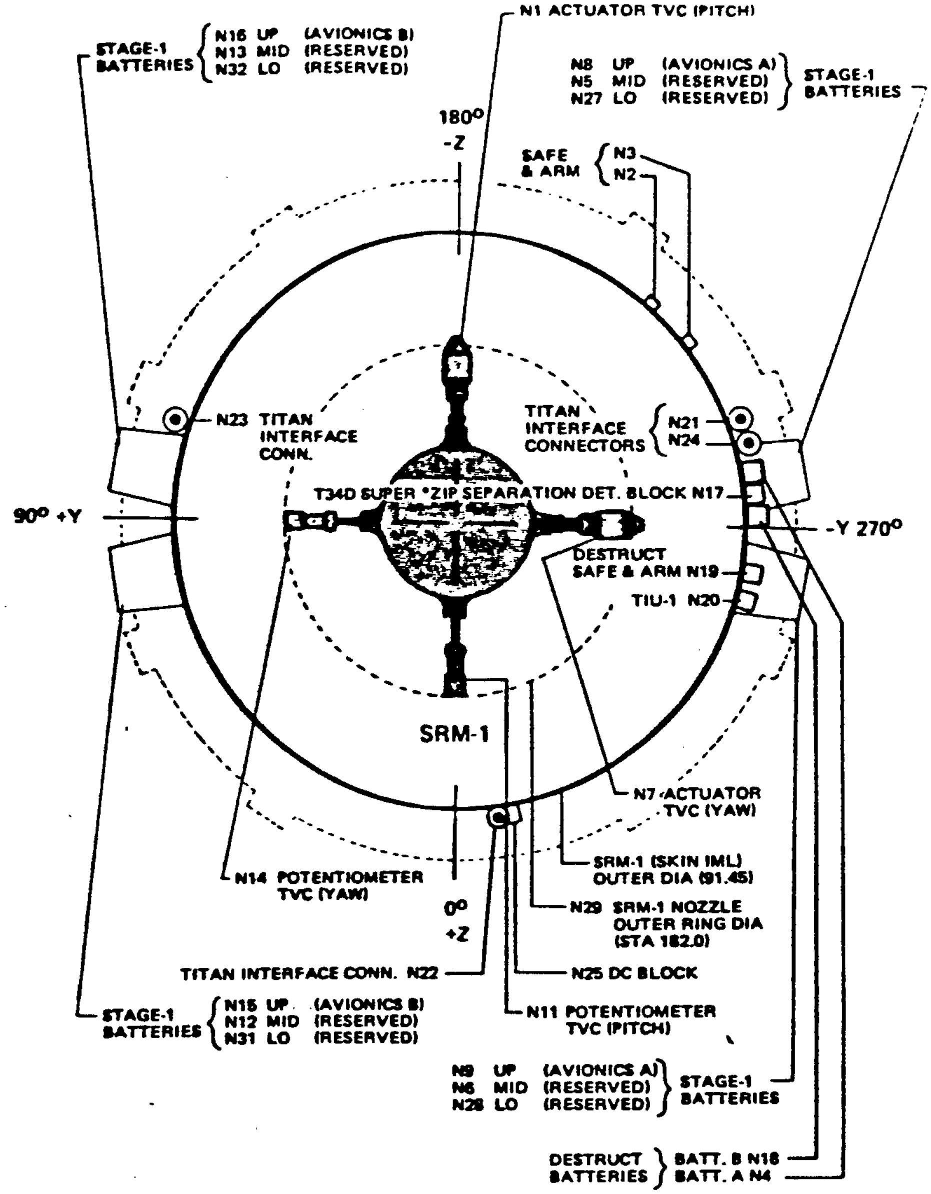
Figure 1.0-4 DOD-T34D Configuration IUS Vehicle



NOTE
COMPONENTS THAT ARE SHADED ARE LOCATED UNDER SRM.

VIEW A-A STAGE 2

Figure 1.0-5 Equipment Support Section (Avionics Bay) (T34D)



VIEW B-B STAGE-1

Figure 1.0-6 IUS Vehicle Equipment Layout (T34D)

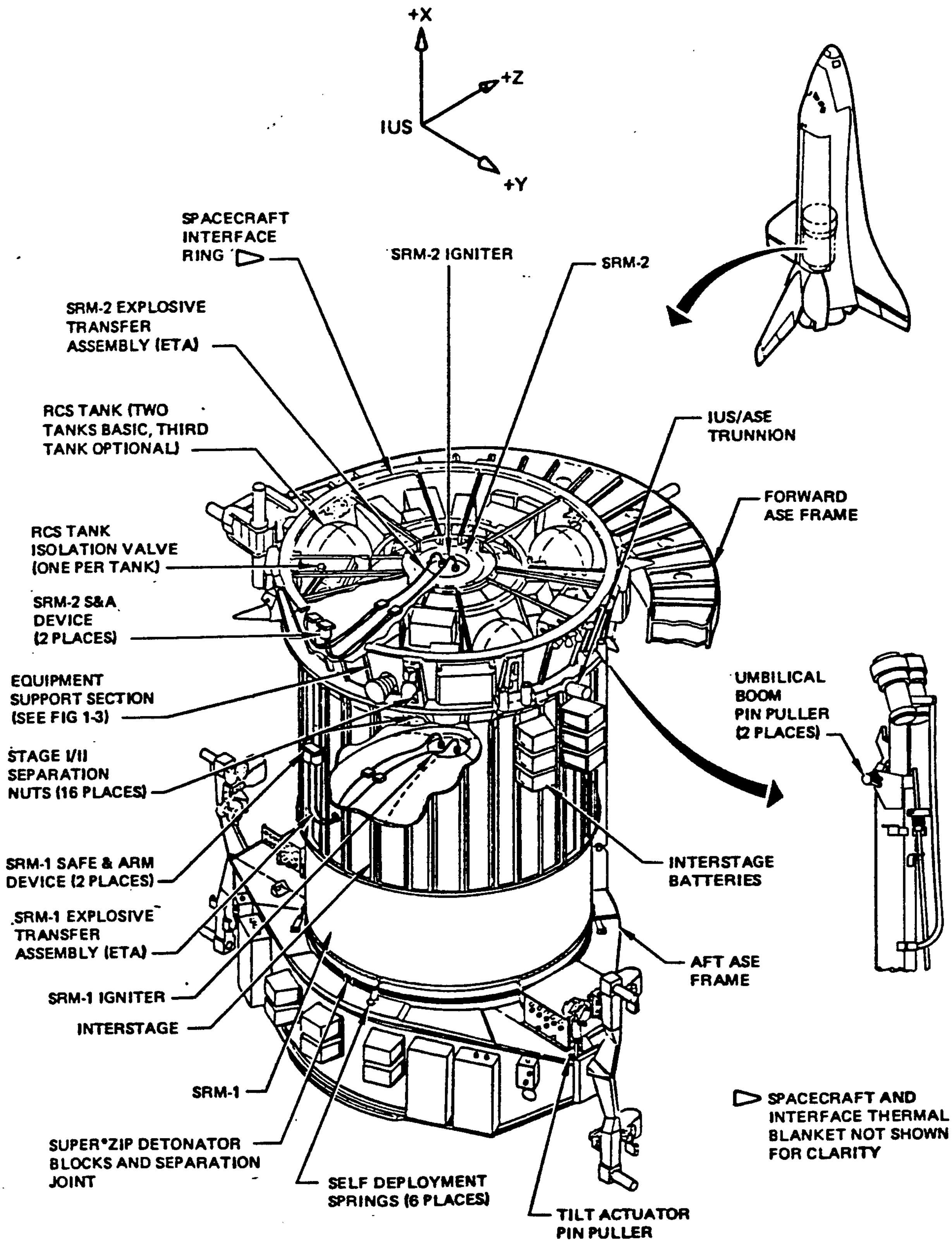


Figure 1.0-7 STS/IUS Two-Stage Vehicle and ASE

Figure 2.1.1-1

PAYLOAD FAIRING SEPARATION SHOCK AT T34D/IUS INTERFACE

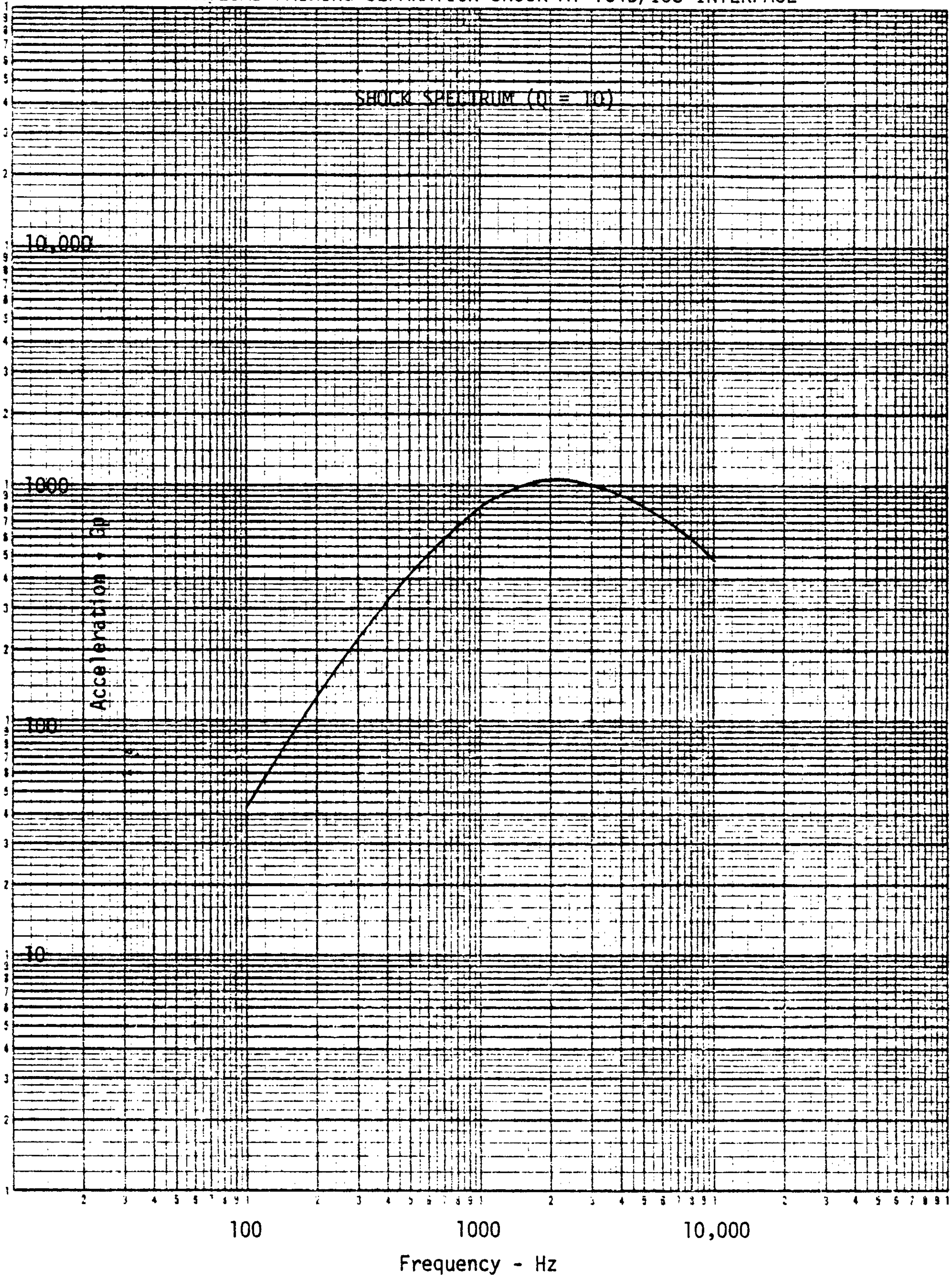


Figure 2.1.2-1

ORBITER INDUCED PYROSHOCK AT IUS ASE/ORBITER INTERFACE

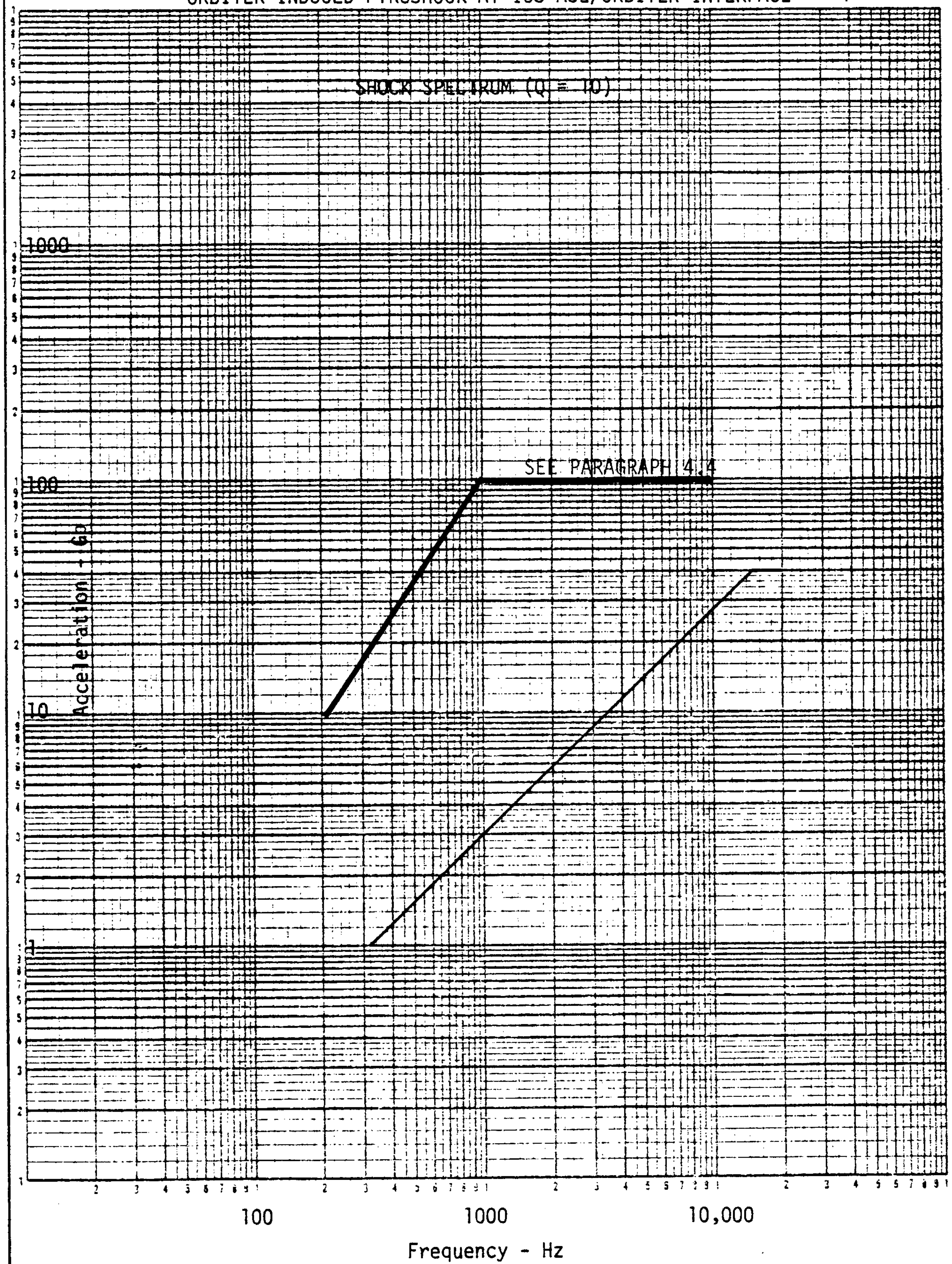


Figure 2.1.3-1

SHOCK RESPONSE SPECTRA DUE TO SPACECRAFT DISTURBANCES

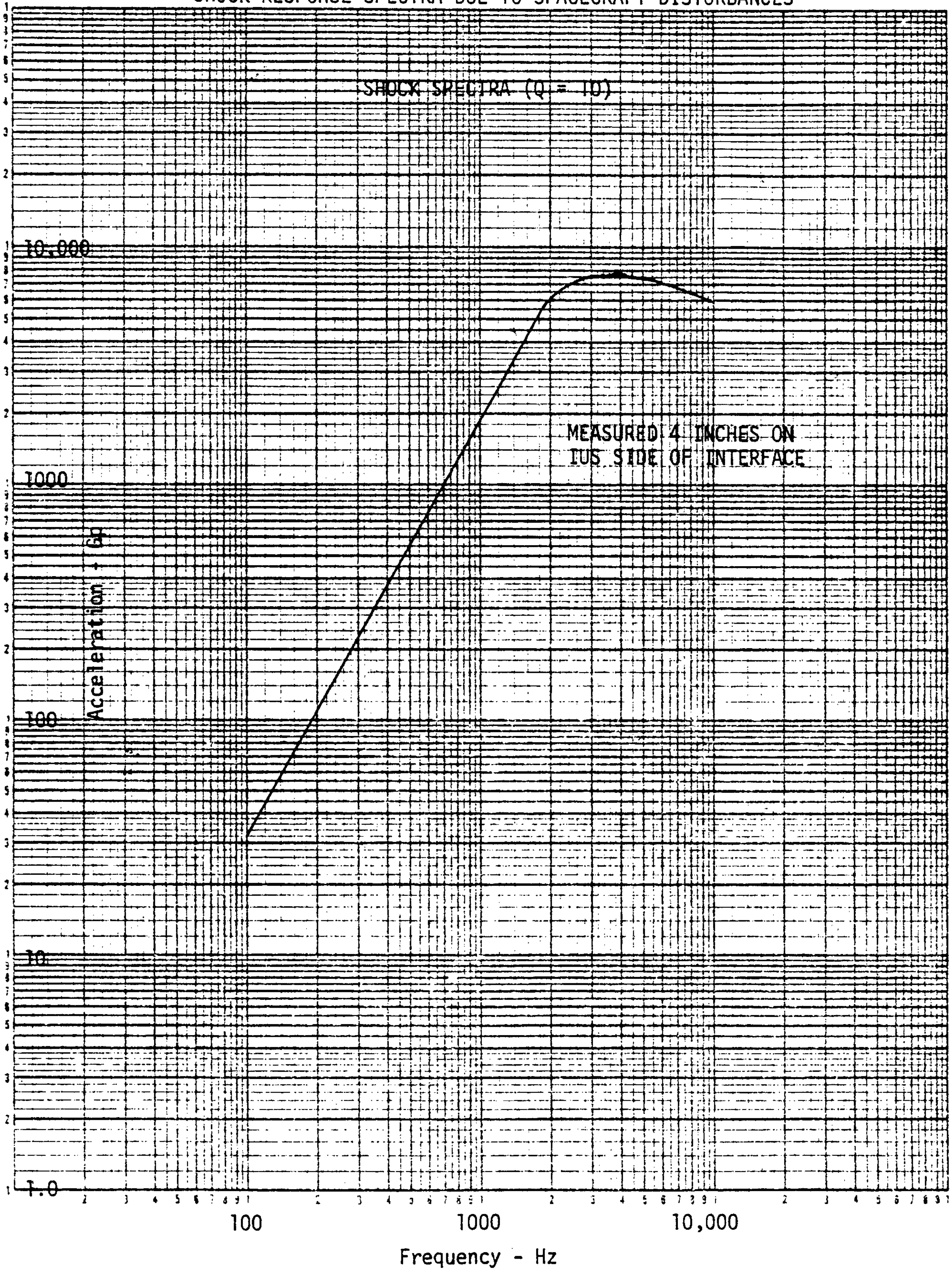


Figure 2.2.2-1

PYROSHOCK CQT REQUIREMENT

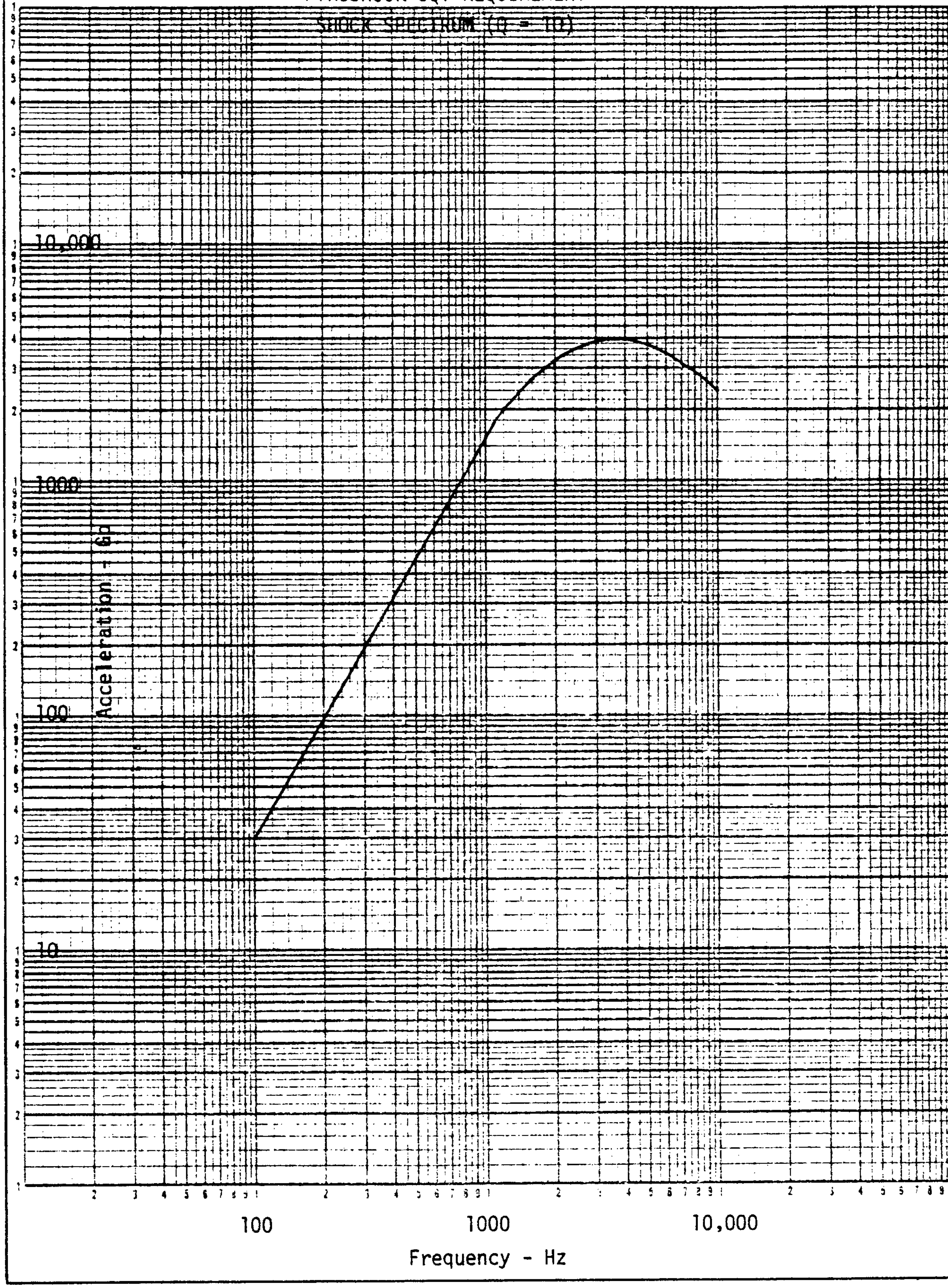


Figure 2.2.2-2

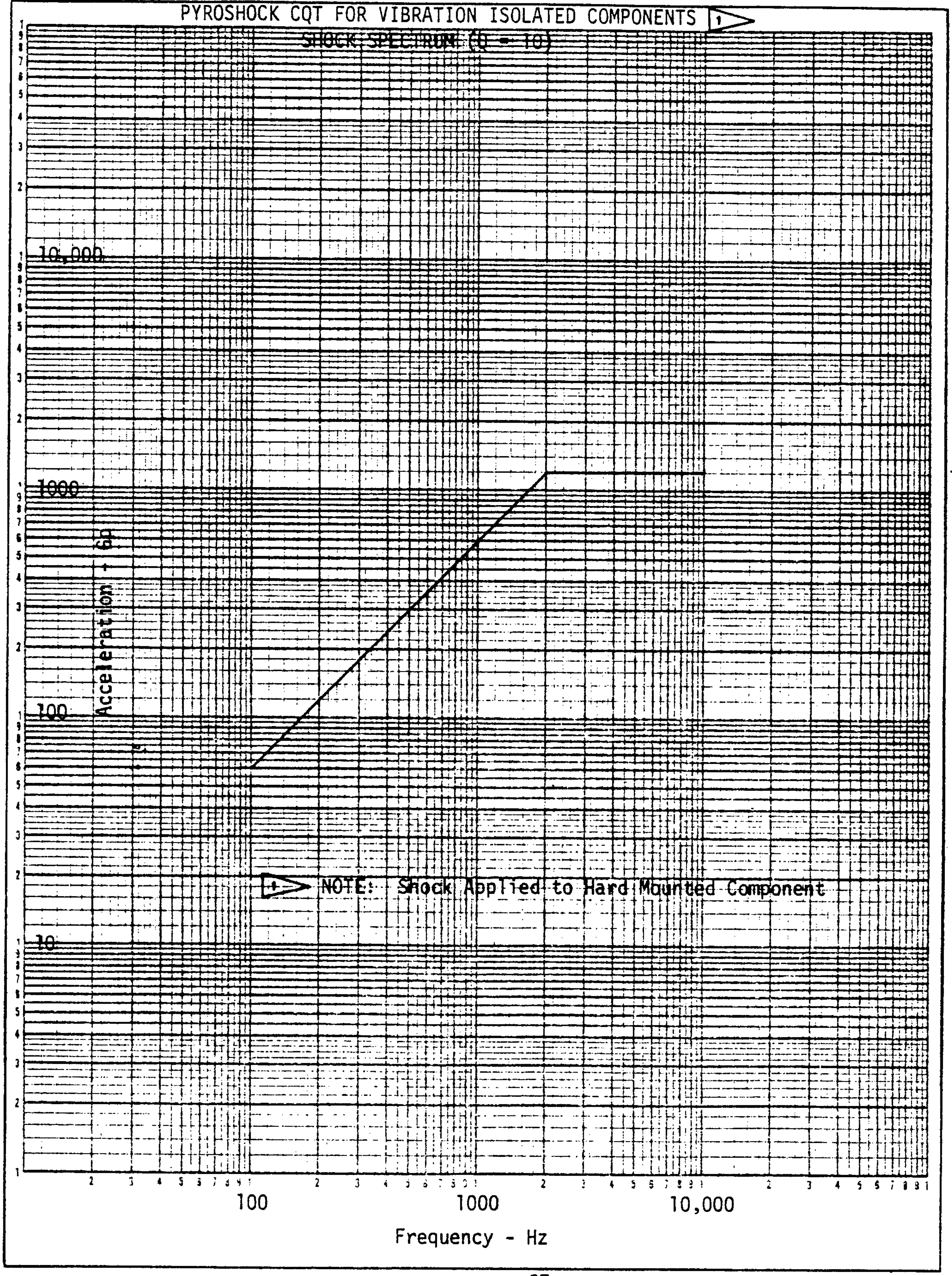

PYROSHOCK CQT FOR VIBRATION ISOLATED COMPONENTS 1
SHOCK SPECTRUM (Q = 10)
Acceleration - Gp
10,000
1000
100
10
1 NOTE: Shock Applied to Hard Mounted Component
100
1000
10,000
Frequency - Hz

Figure 2.2.2-3

COMPUTER PYROSHOCK CQT REQUIREMENT

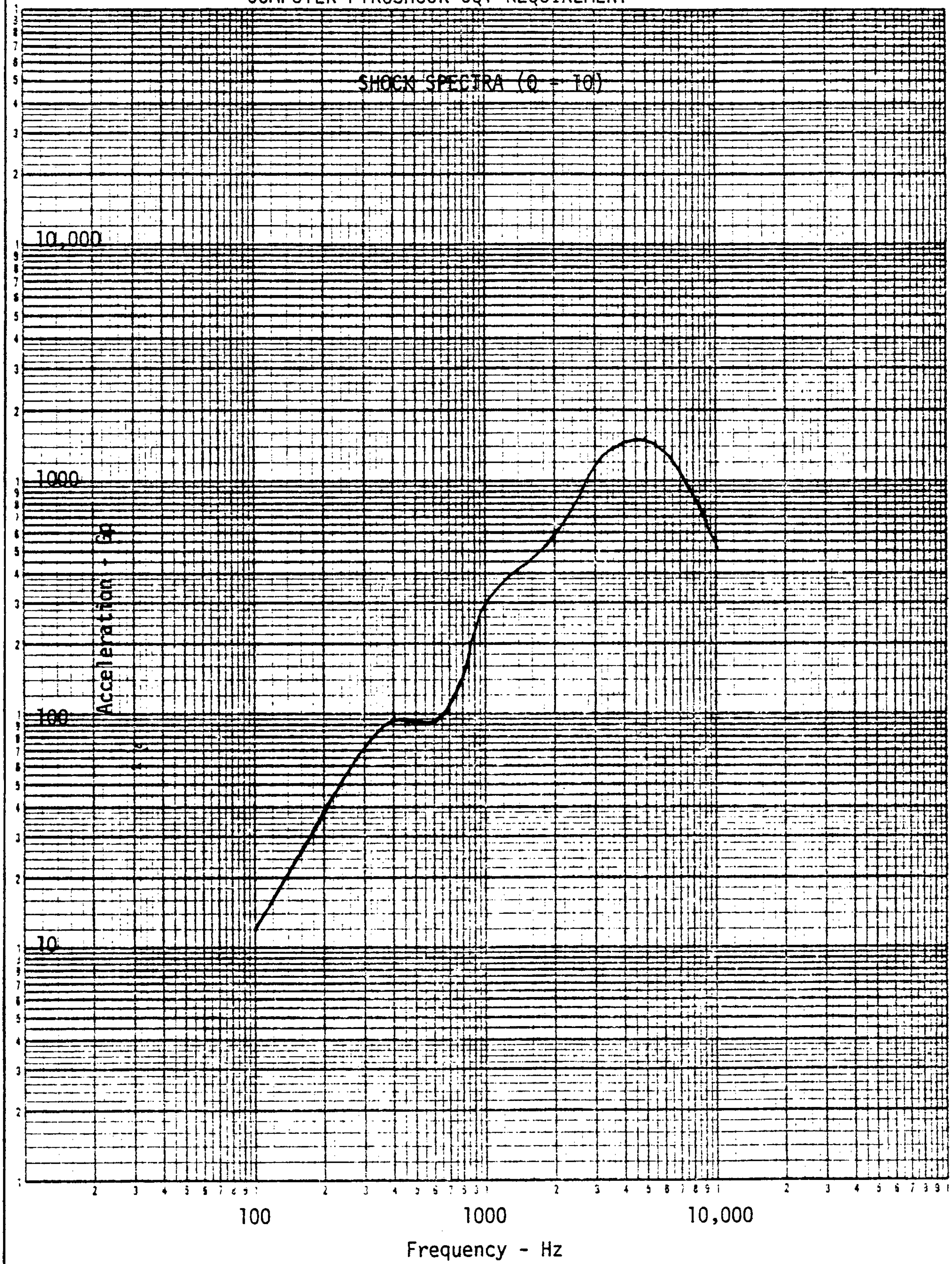


Figure 2.2.2-4

RF SWITCH PYROSHOCK CQT REQUIREMENT

SHOCK SPECTRUM (Q = 10)

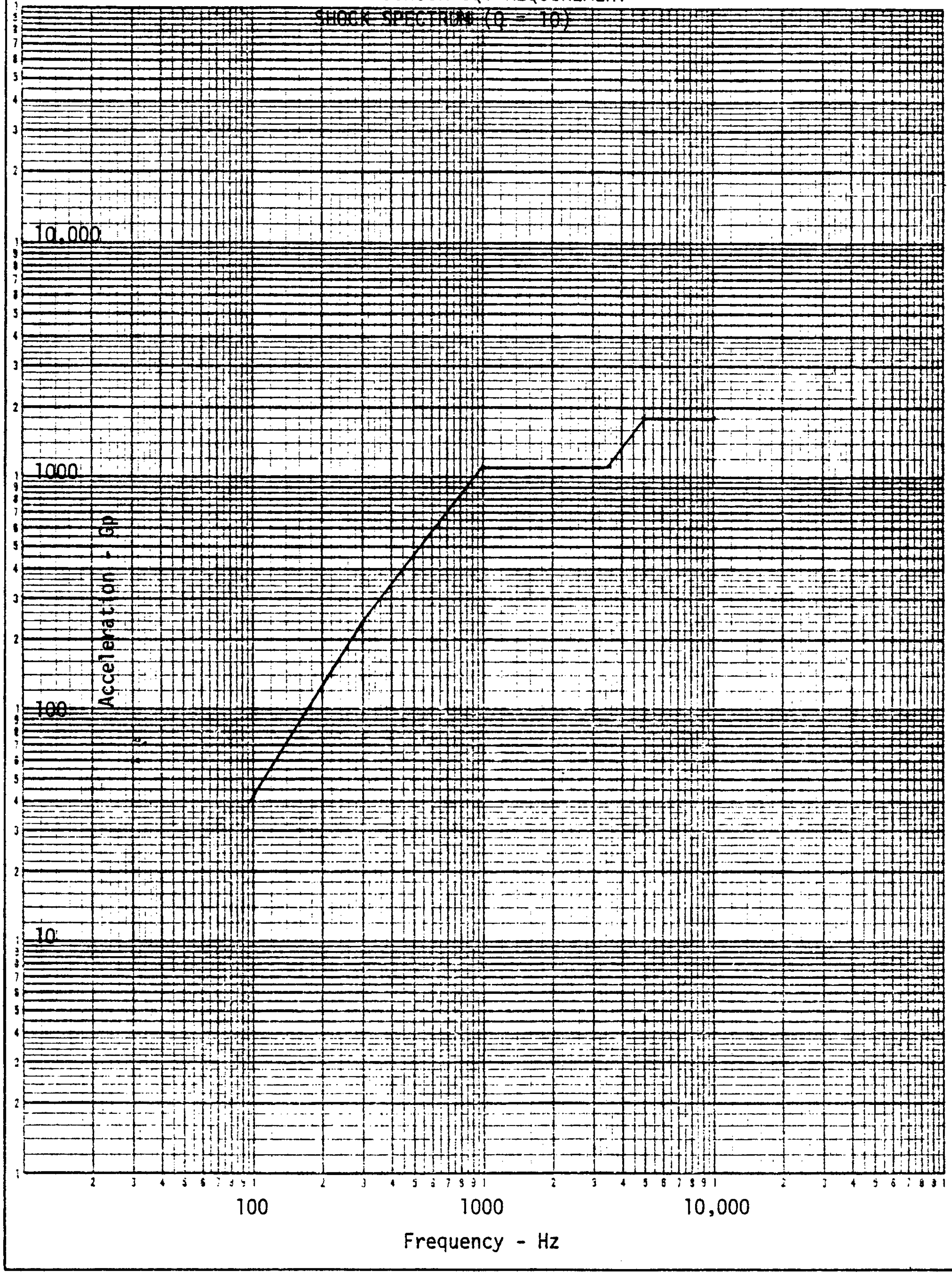


Figure 2.2.2-5

280- 41012 SEPARATION SWITCH PYROSHOCK CQT REQUIREMENT

SHOCK SPECTRUM (Q = 10)

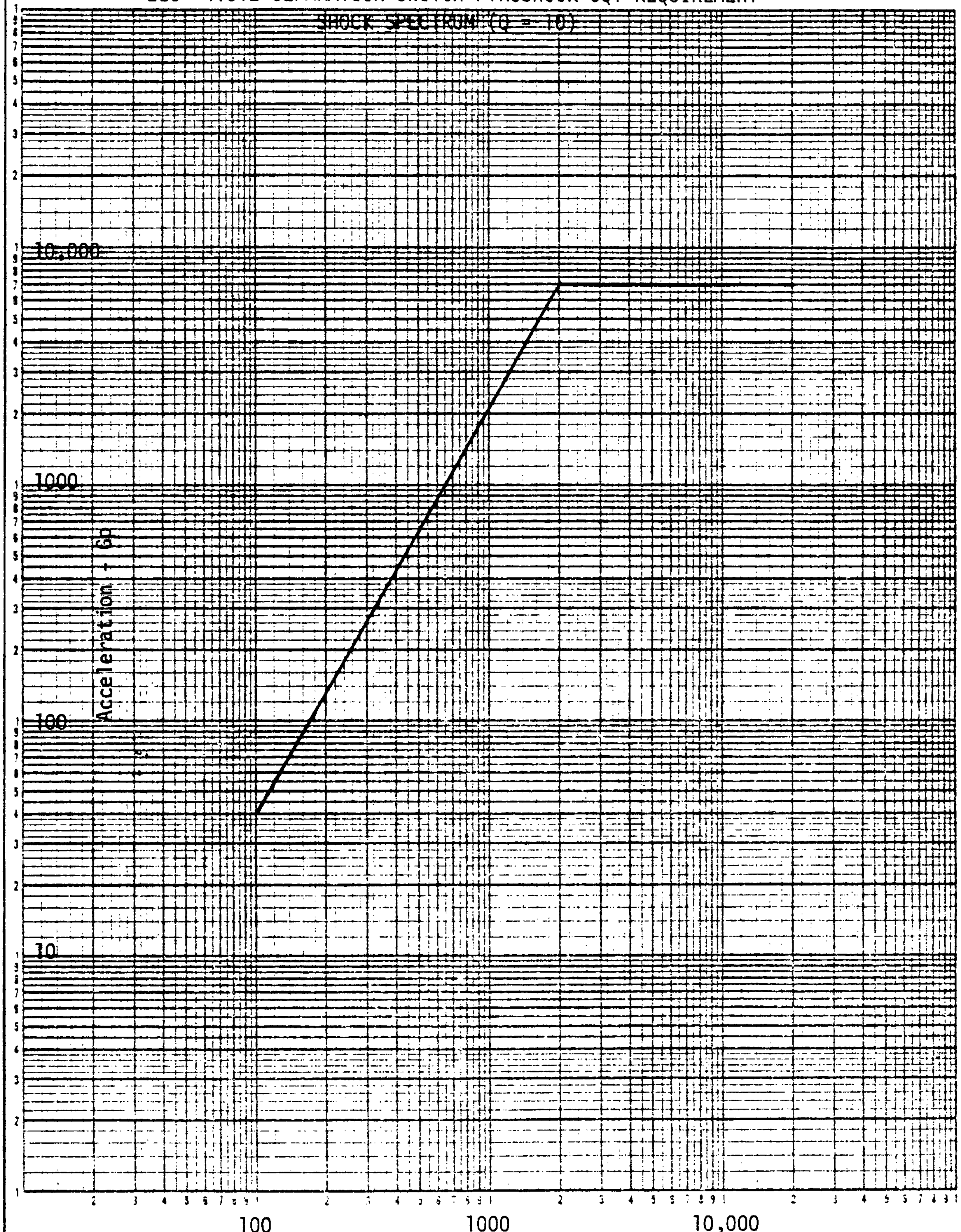


Figure 2.2.2-6

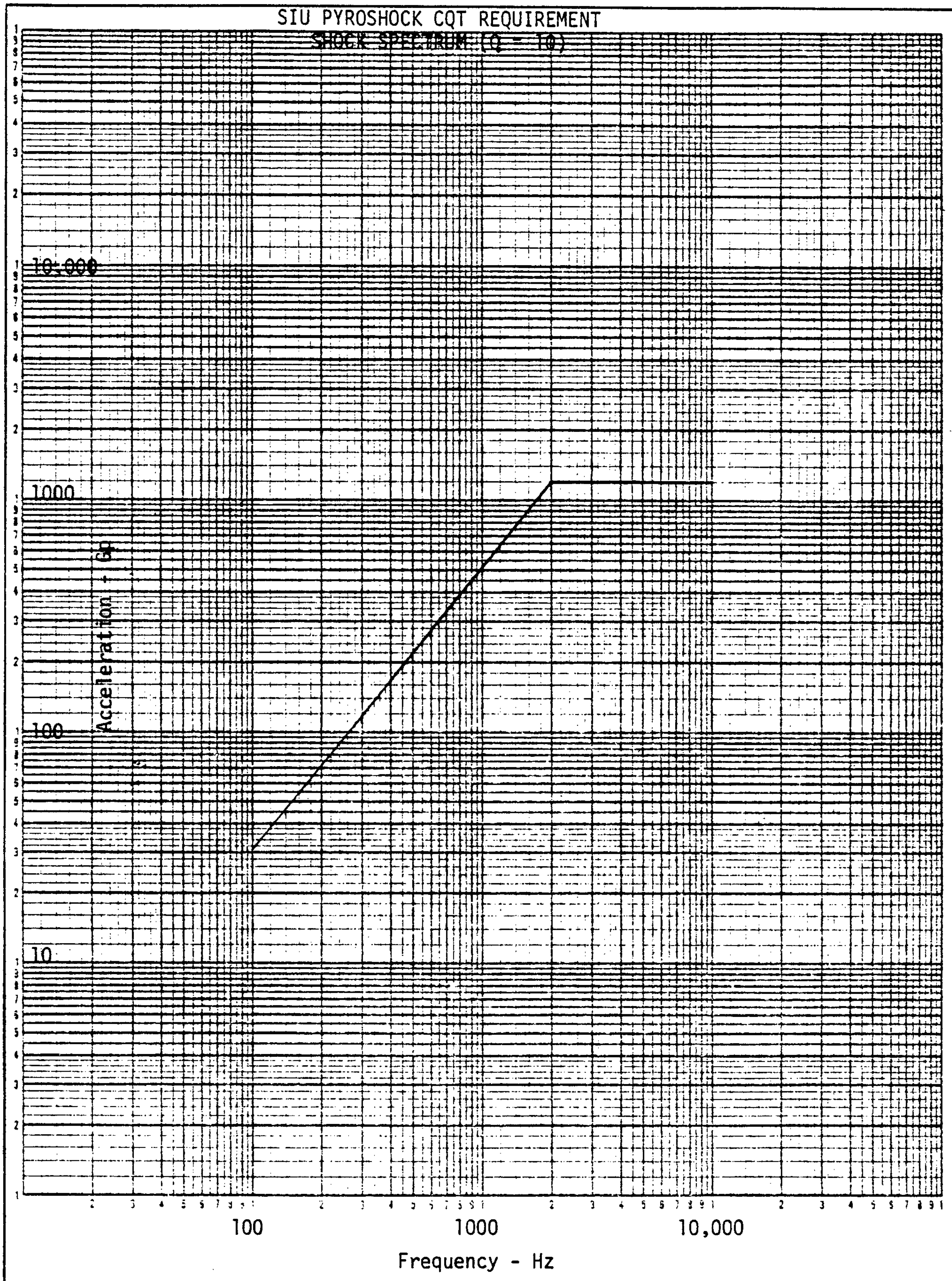

SIU PYROSHOCK CQT REQUIREMENT
SHOCK SPECTRUM (Q = 10)
10,000
1000
100
10
Acceleration - G's
100
1000
10,000
Frequency - Hz

Figure 2.2.2-7
SCU PYROSHOCK CQT REQUIREMENT
SHOCK SPECTRUM (Q = 10)

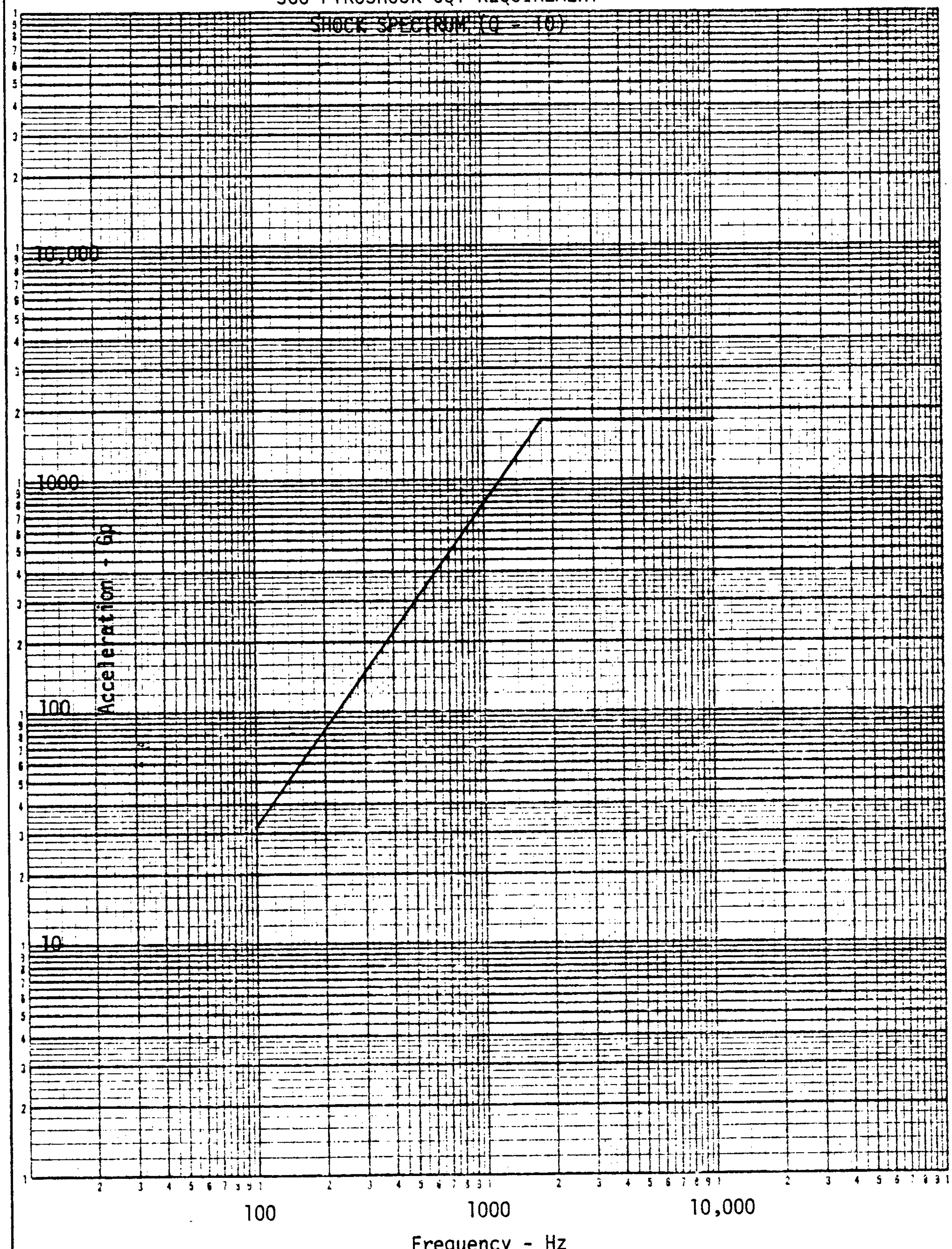


Figure 2.2.2-8

Separation Connector Pyroshock CQT Requirement

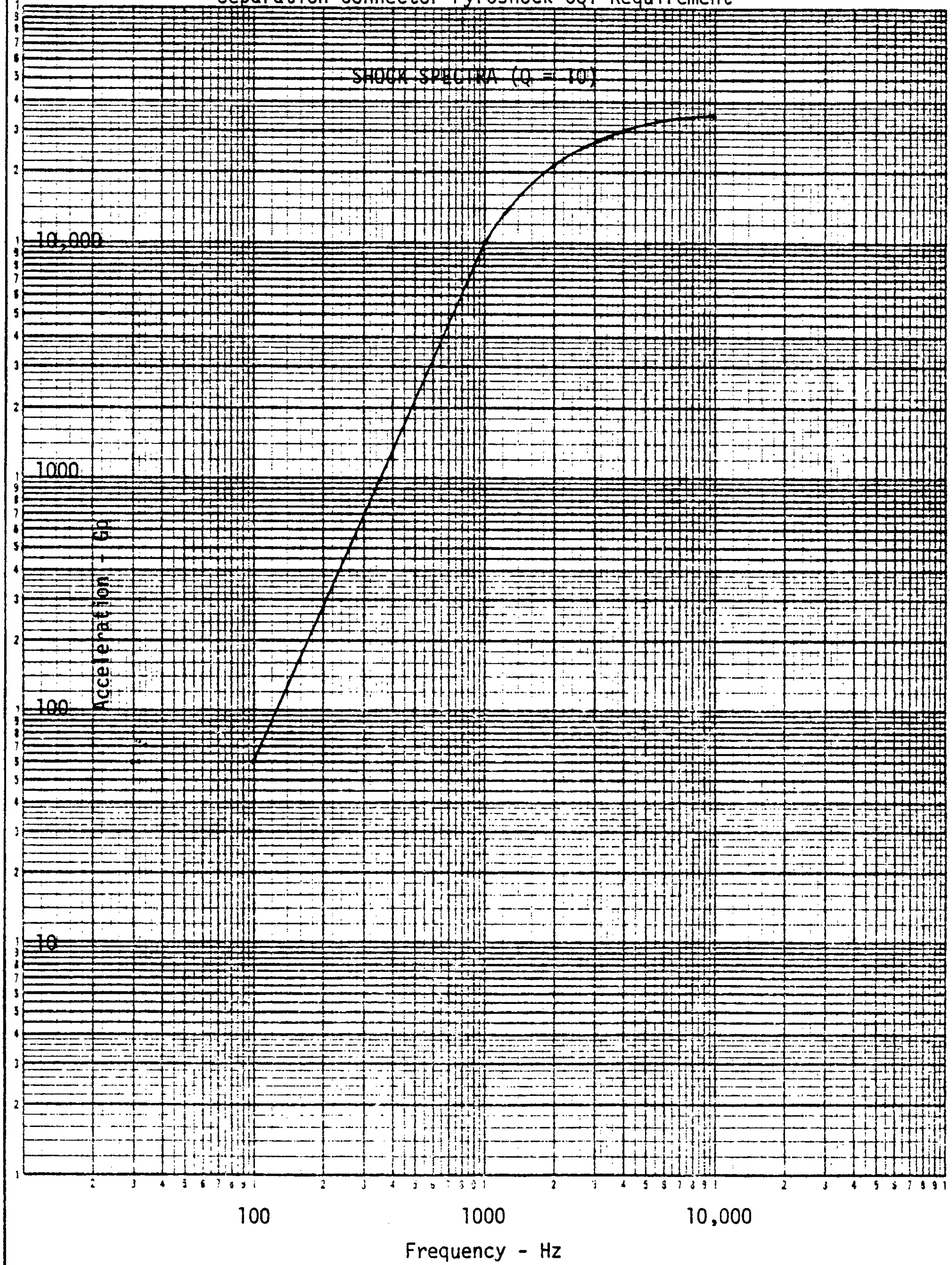


Figure 2.2.2-9
PYRO-CONNECTOR PYROSHOCK CQT REQUIREMENT

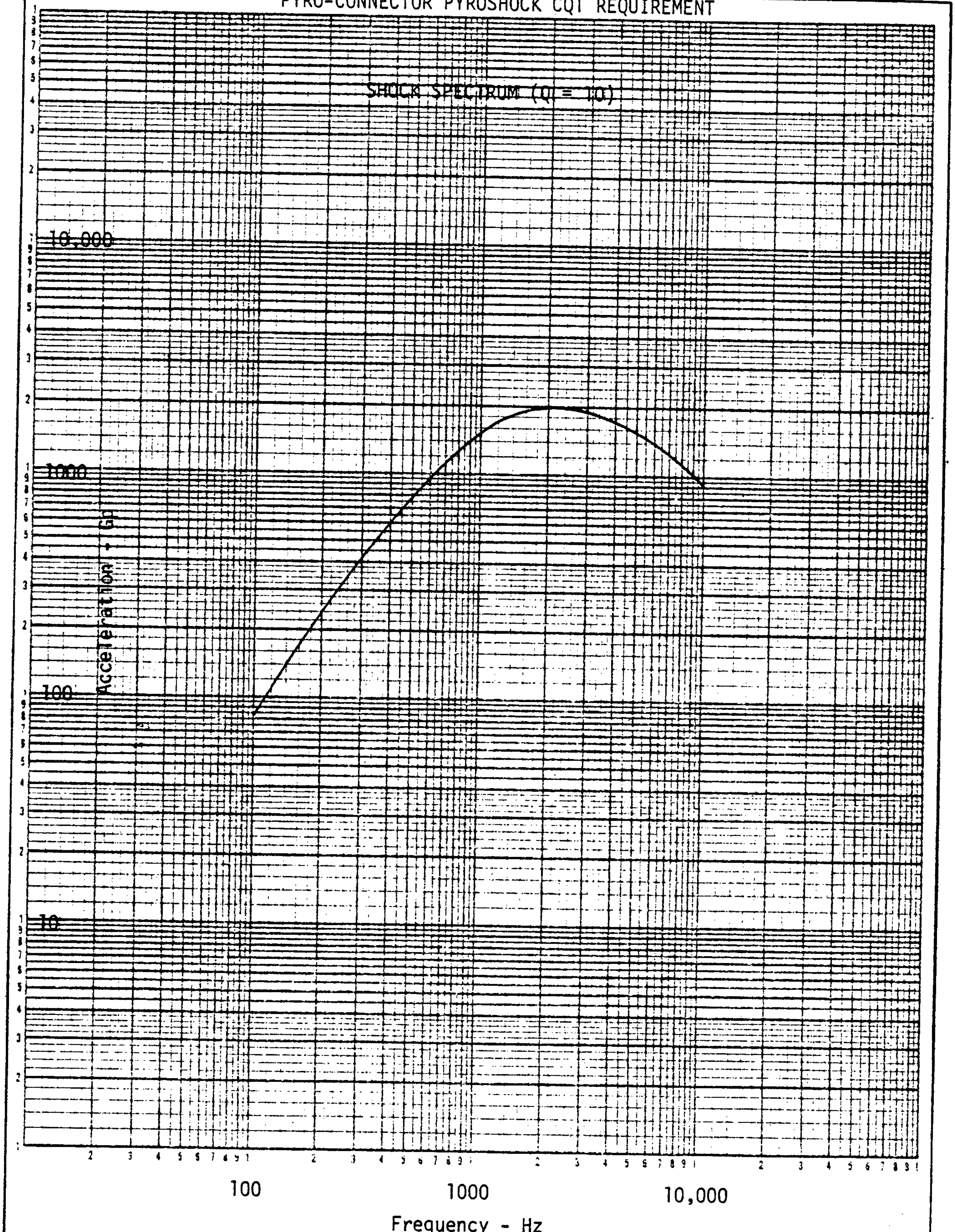


Figure 2.3.1-1

PYROSHOCK DATA REDUCTION PROCESS

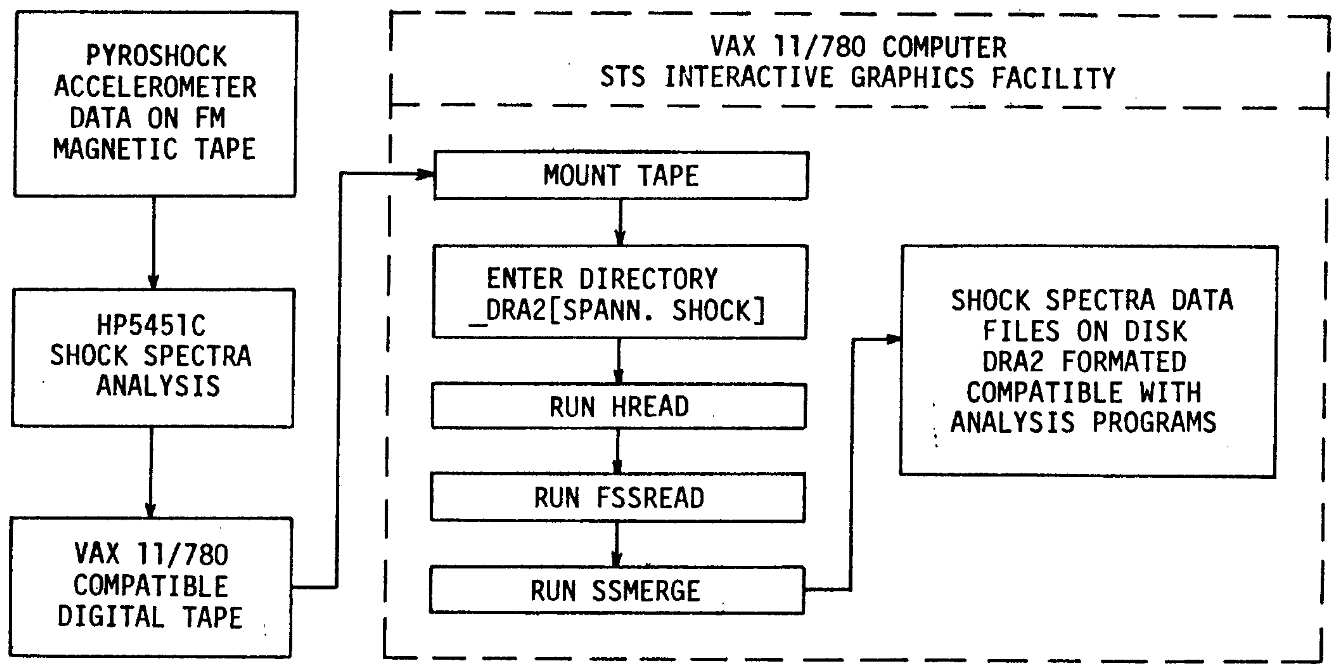
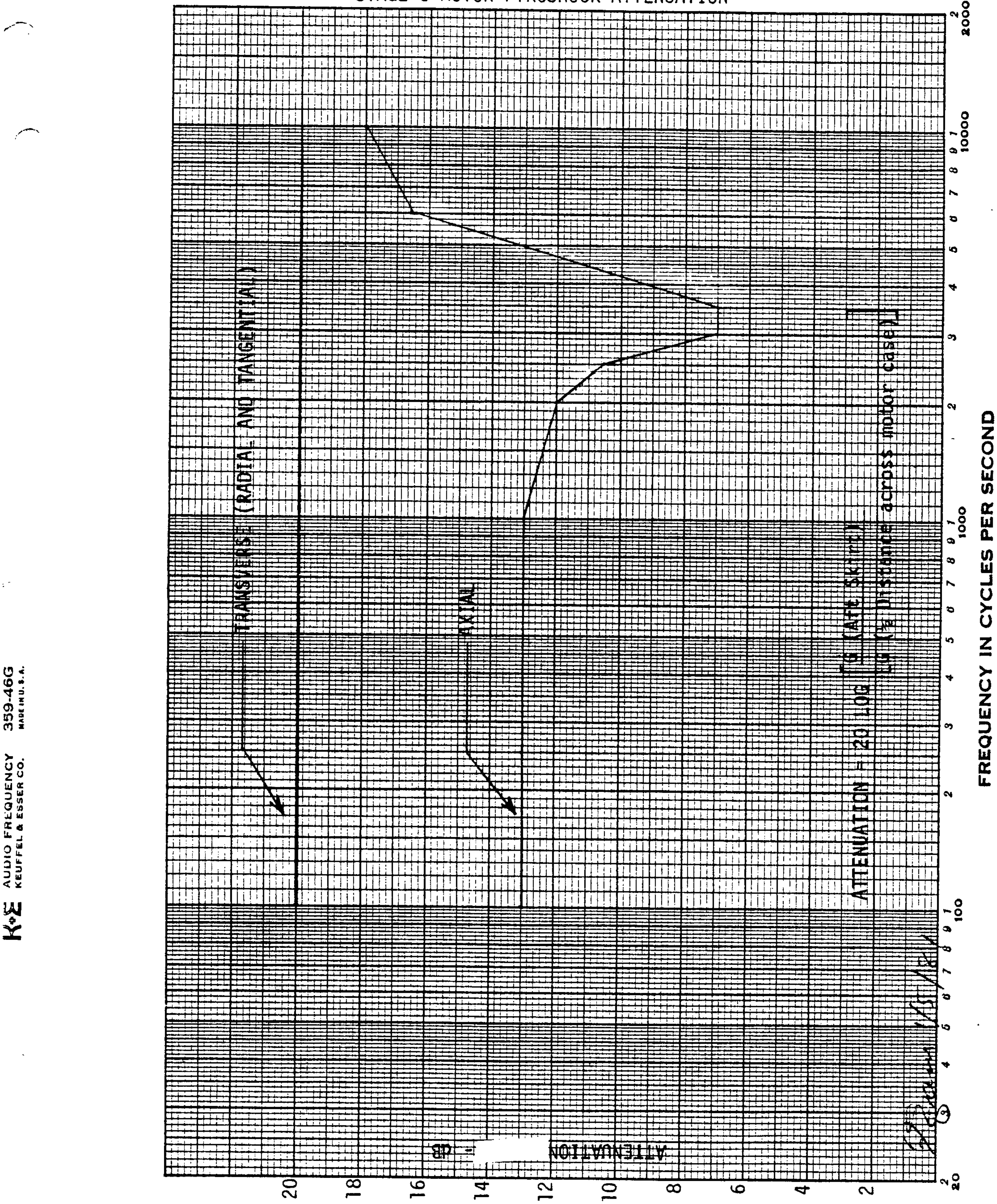


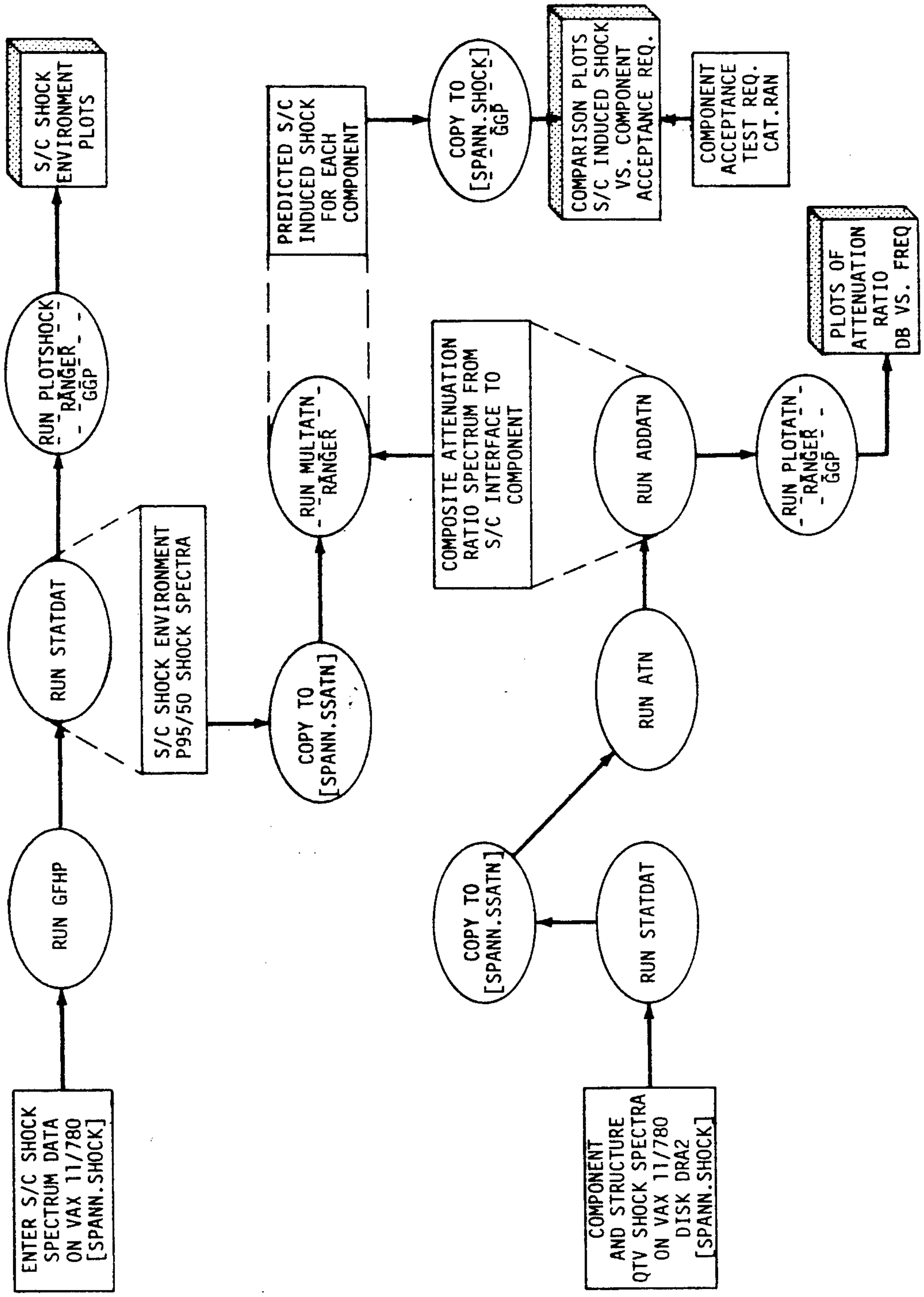
Figure 2.3.3.2-1
STAGE I MOTOR PYROSHOCK ATTENUATION



Figures 2.3.3.3-2 through 2.3.3.3-11
have been deleted from the orginal release
for Revision A (pages 47 through 56).

Figure 2.3.3.3-1 has been replaced with
"S/C Induced Shock Prediction Flow Diagram"
for Revision A (page 46).

Figure 2.3.3.3-1 S/C Induced Shock Prediction Flow Diagram



D0 6000 2145 ORIG. 4/71

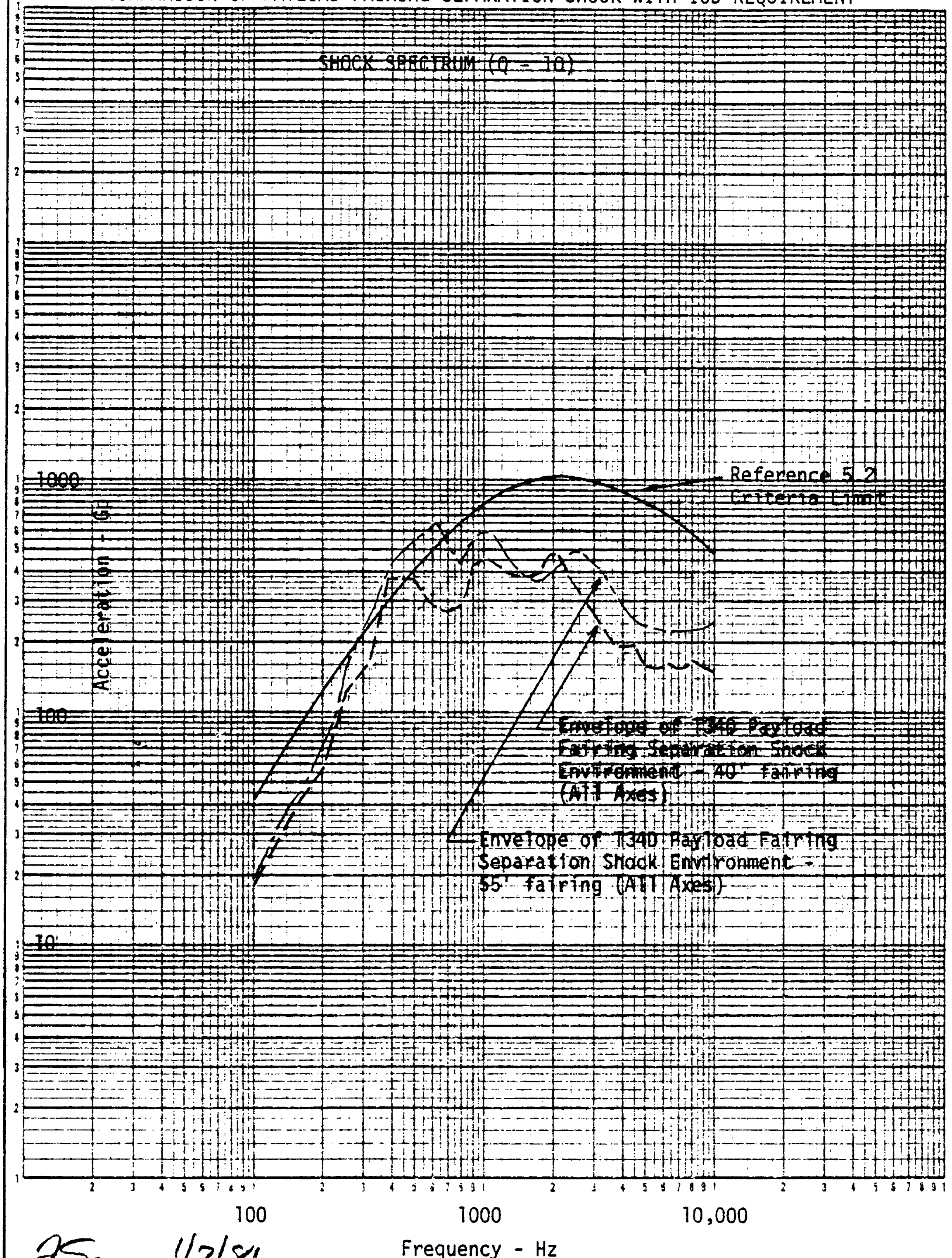
Figure 2.3.4-1

Transfer Function Calculation Program

```
10 REM ** ** ** ** ** ** DIVIDE.BAS ** ** ** ** ** ** ** **
11 PRINT "            THIS IS A PROGRAM TO CALCULATE THE TRANSFER"
12 PRINT "            FUNCTION FROM TWO FILES."
15 PRINT
16 PRINT "            THE PROGRAM DIVIDES FILE 2 BY FILE 1."
20 DIM F(600),D(600),N(600),T(600)
50 INPUT "ENTER FILE #1 FILENAME (DENOMINATOR)";N1$
55 OPEN N1$ FOR INPUT AS FILE 1%
60 INPUT "ENTER FILE #2 FILENAME (NUMERATOR)";N2$
65 OPEN N2$ FOR INPUT AS FILE 2%
68 PRINT
70 INPUT "ENTER A FILENAME FOR TRANSFER FUNCTION (.GGP)";N5$
75 OPEN N5$ FOR OUTPUT AS FILE 5%
100 LINPUT#1%,T1$
110 INPUT#1%,NPTS,DF,FMAX
115 J=NPTS
140 FOR I = 1 TO J
150 INPUT#1%,D(I)
160 NEXT I
200 LINPUT#2%,T3$
210 LINPUT#2%,T4$
240 FOR I = 1 TO J
250 INPUT#2%,N(I)
260 NEXT I
300 FOR I = 1 TO J
310 F(I)=I*DF
320 NEXT I
400 FOR I = 1 TO J
410 T(I)=N(I)/D(I)
411 T(I)=T(I)**.5
420 NEXT I
590 PRINT#5%,"*OPT"
600 PRINT#5%,"*RUN 16"
610 PRINT#5%,"+01 FREQUENCY - HERTZ"
620 PRINT#5%,"+02 TRANSFER FUNCTION"
630 PRINT#5%,"$ TRANSFER FUNCTION FOR"
640 PRINT#5%,"$";N2$;" DIVIDED BY ";N1$
650 PRINT#5%,"TRANFUN"
660 PRINT#5%,"FREQ","TRAN"
670 FOR I = 1 TO J
680 PRINT#5%, F(I),T(I)
690 NEXT I
700 PRINT#5%,"*EOF"
800 PRINT
810 PRINT
820 PRINT
850 PRINT " A PLOT FILE ";N5$;" HAS BEEN CREATED"
851 PRINT " WHICH IS THE DIVISION OF ";N2$;" BY ";N1$
5000 END
```

Figure 3.1.1-1

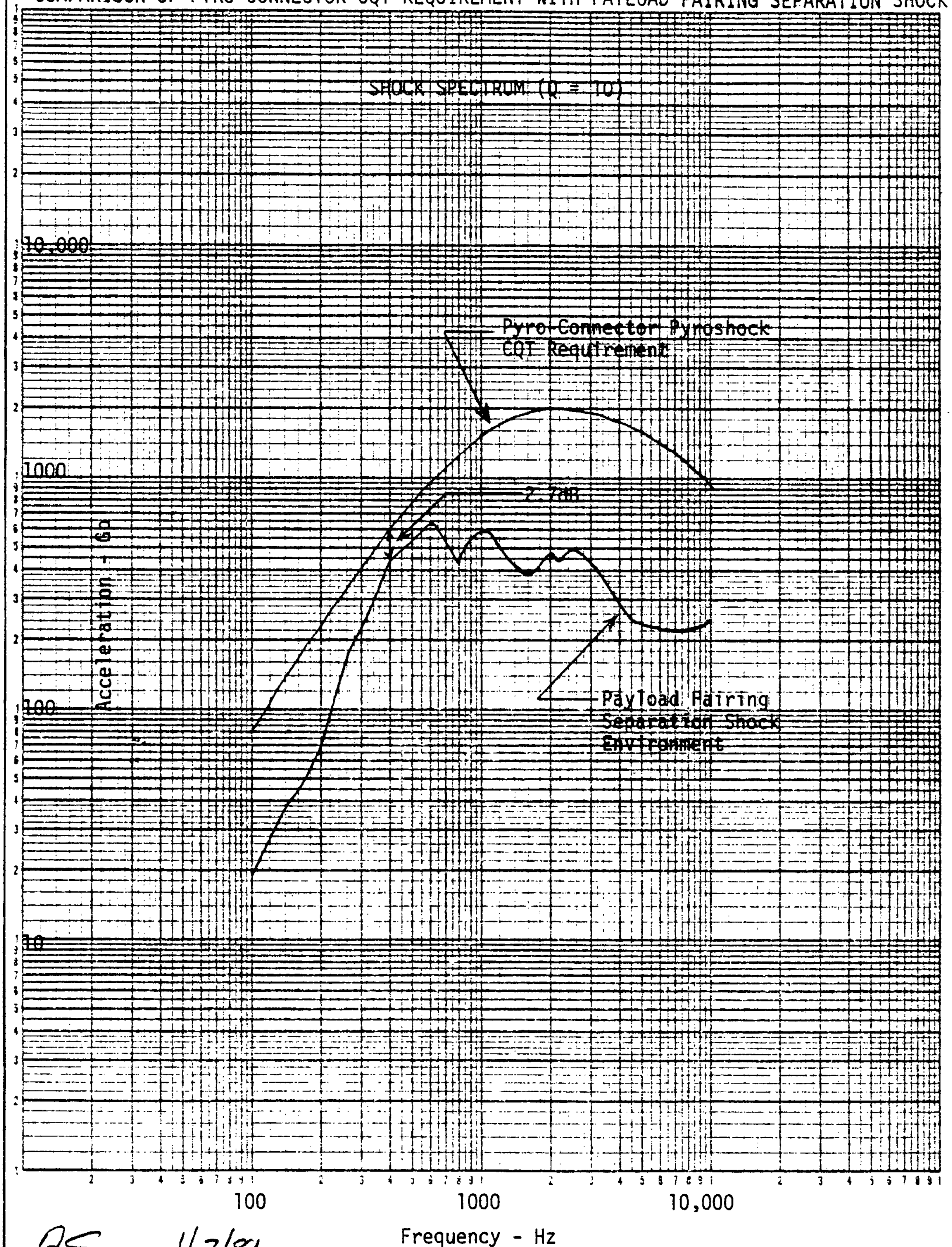
COMPARISON OF PAYLOAD FAIRING SEPARATION SHOCK WITH ICD REQUIREMENT



1/7/81

Figure 3.1.1-2

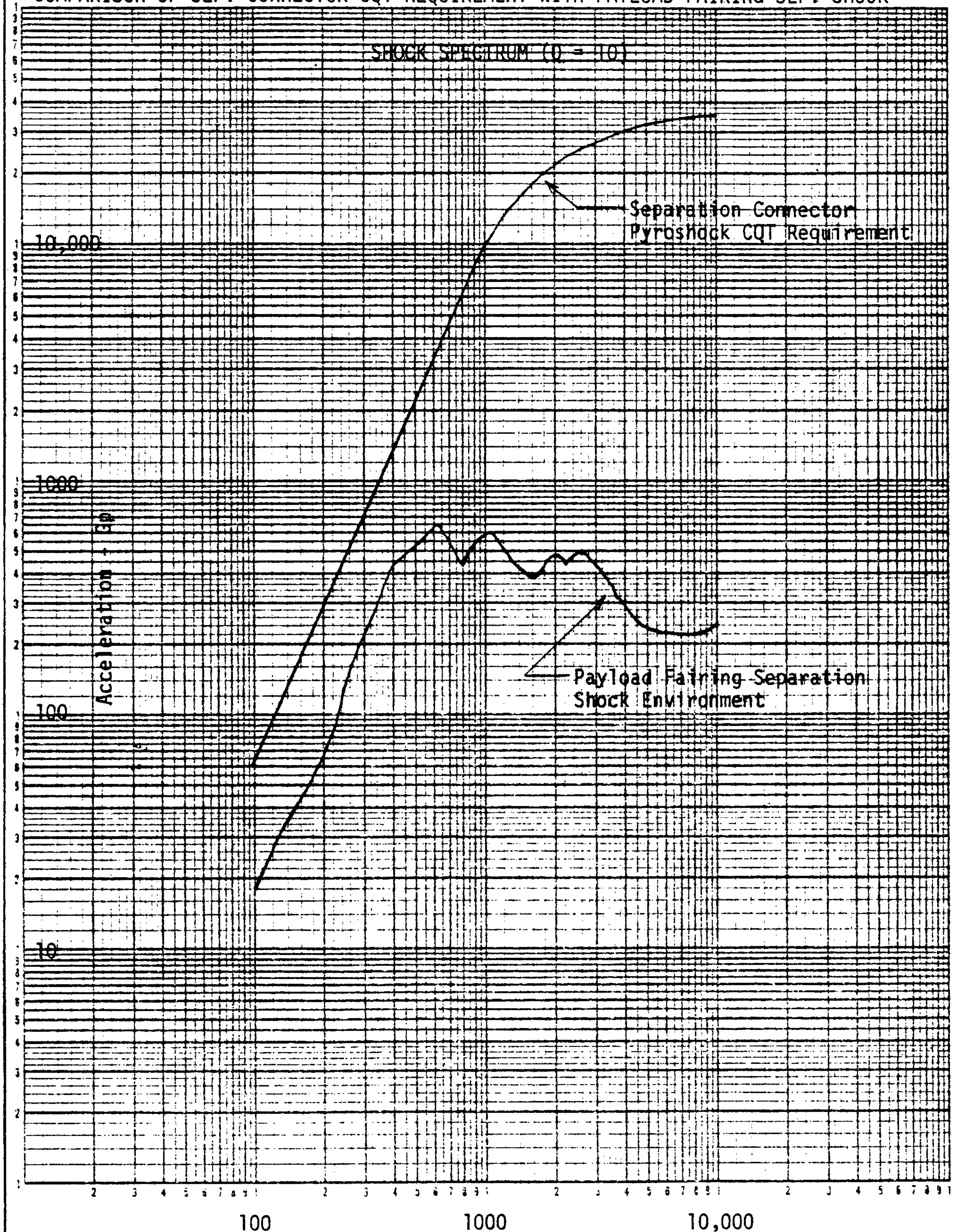
COMPARISON OF PYRO-CONNECTOR CQT REQUIREMENT WITH PAYLOAD FAIRING SEPARATION SHOCK



F. Evans 1/7/81

Figure 3.1.1-3

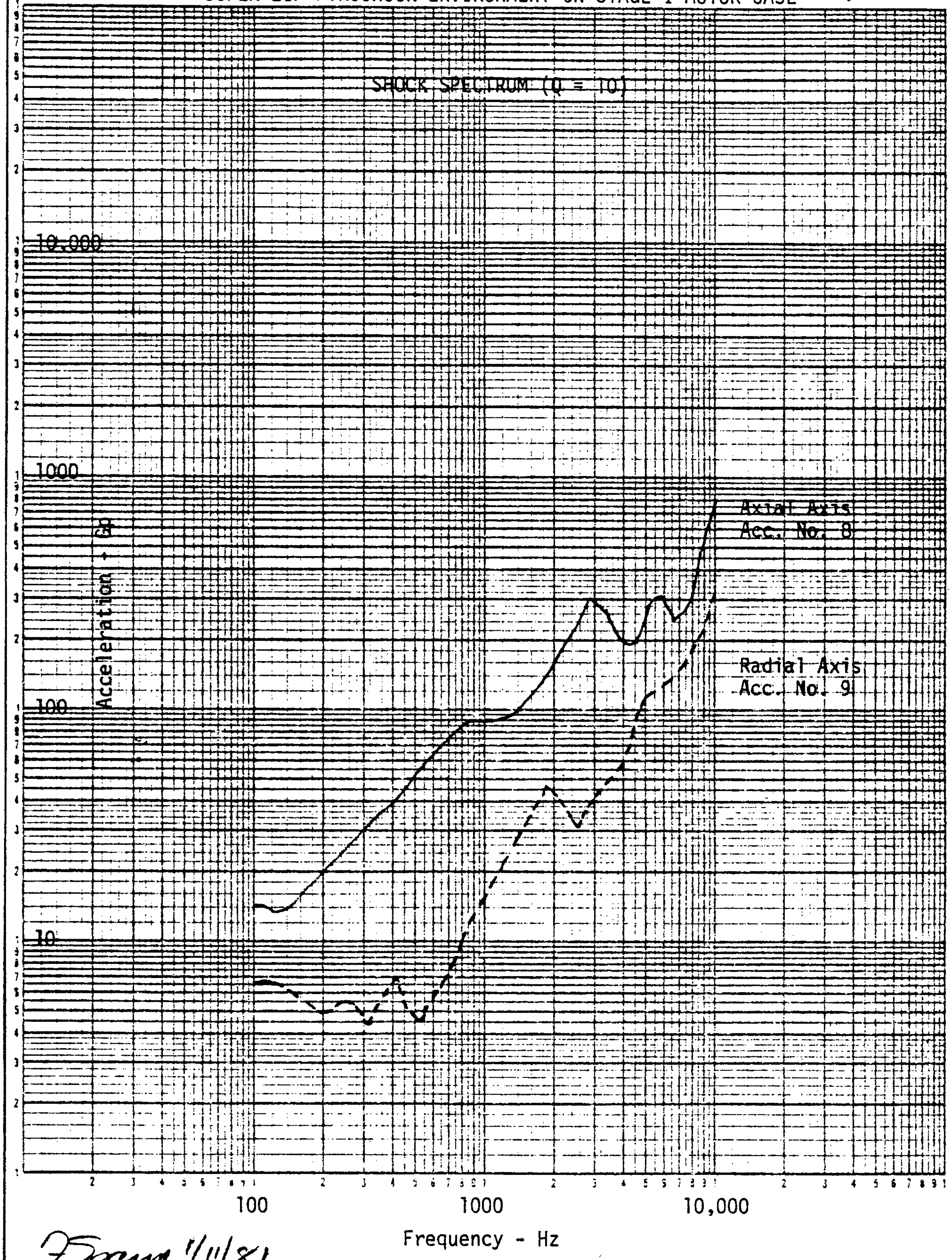
COMPARISON OF SEP. CONNECTOR CQT REQUIREMENT WITH PAYLOAD FAIRING SEP. SHOCK



F. Evans 1/7/81

Figure 3.1.2.1-1

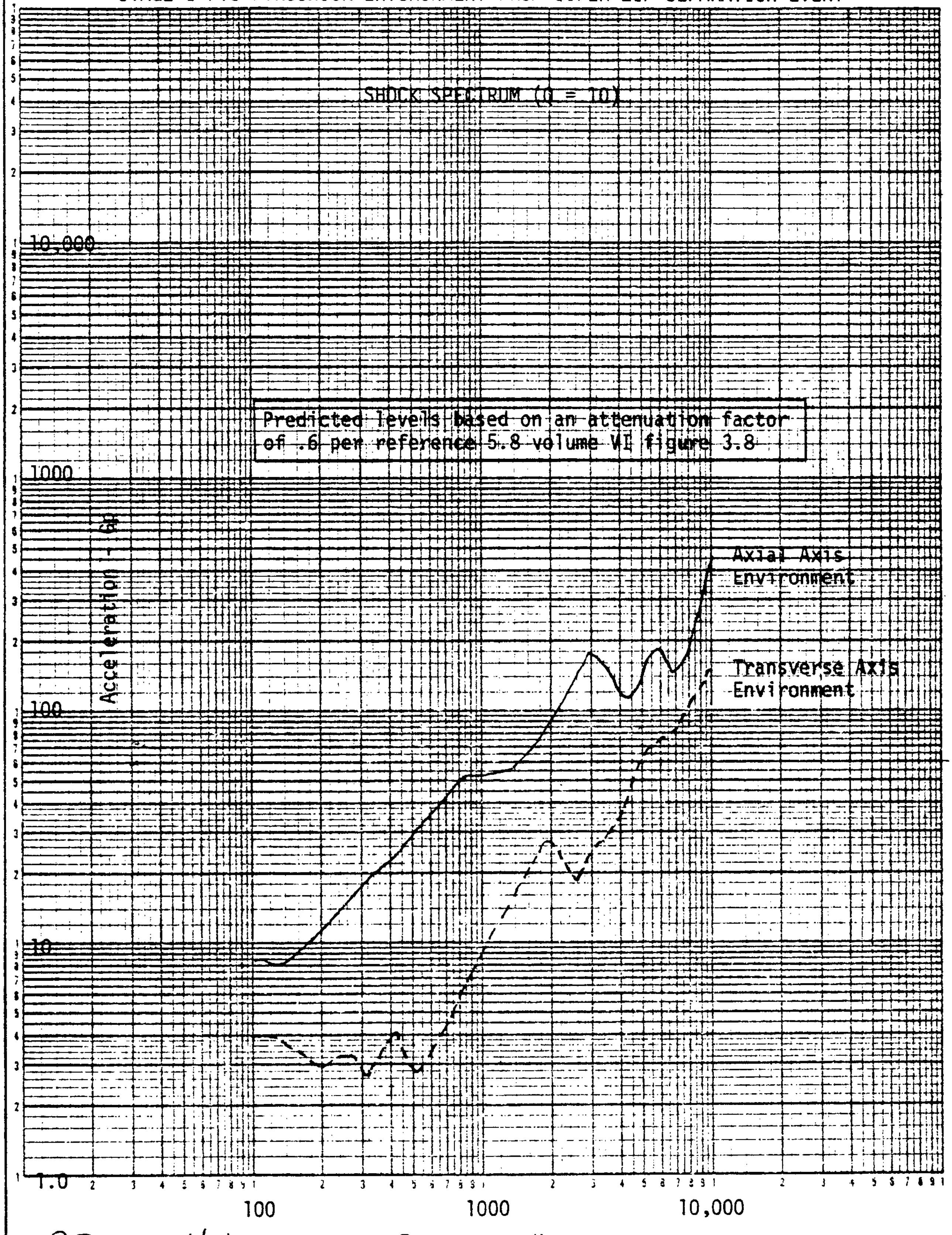
SUPER*ZIP PYROSHOCK ENVIRONMENT ON STAGE I MOTOR CASE



Fzang 1/11/81

Figure 3.1.2.1-2

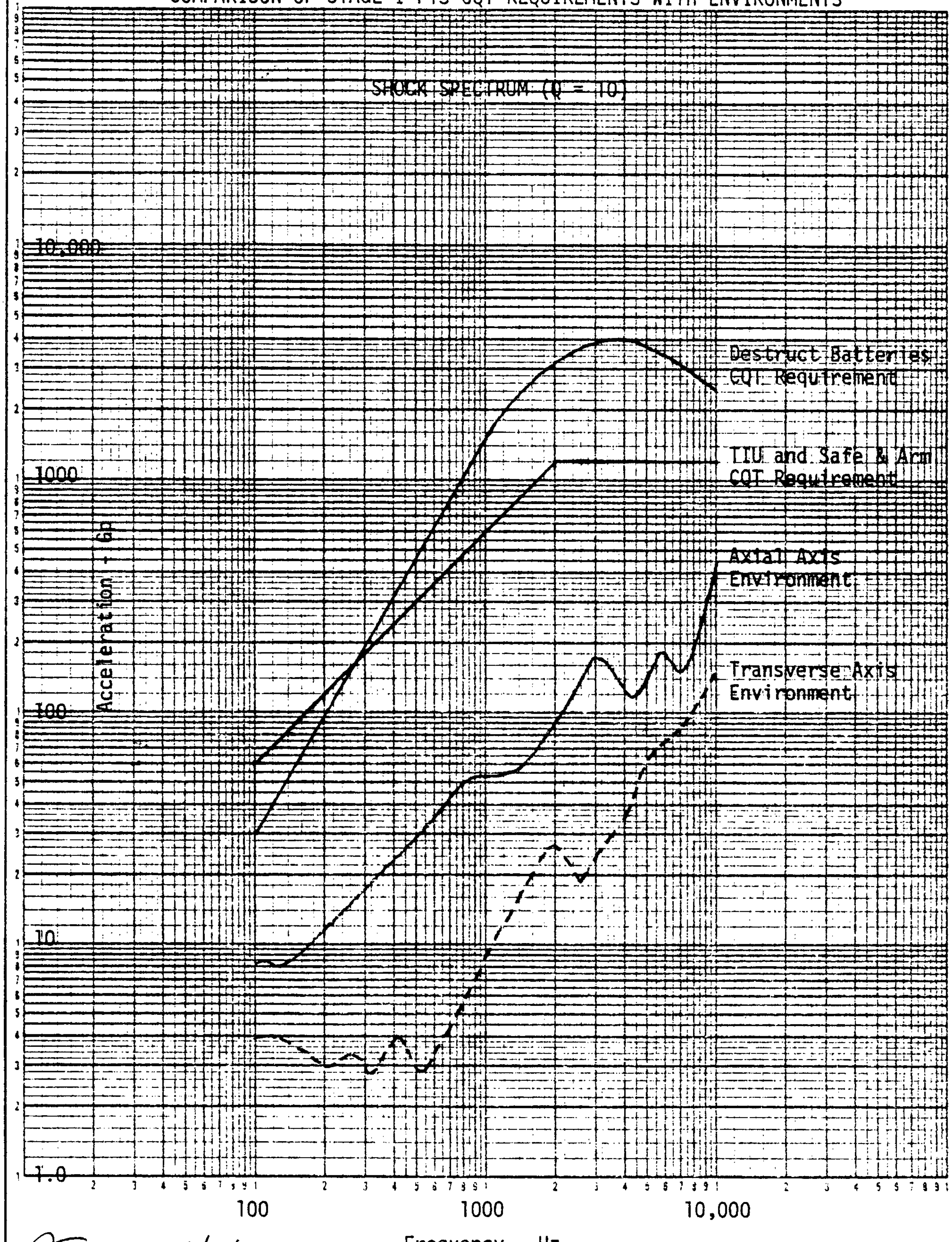
STAGE I FTS PYROSHOCK ENVIRONMENT FROM SUPER*ZIP SEPARATION EVENT



1/11/81

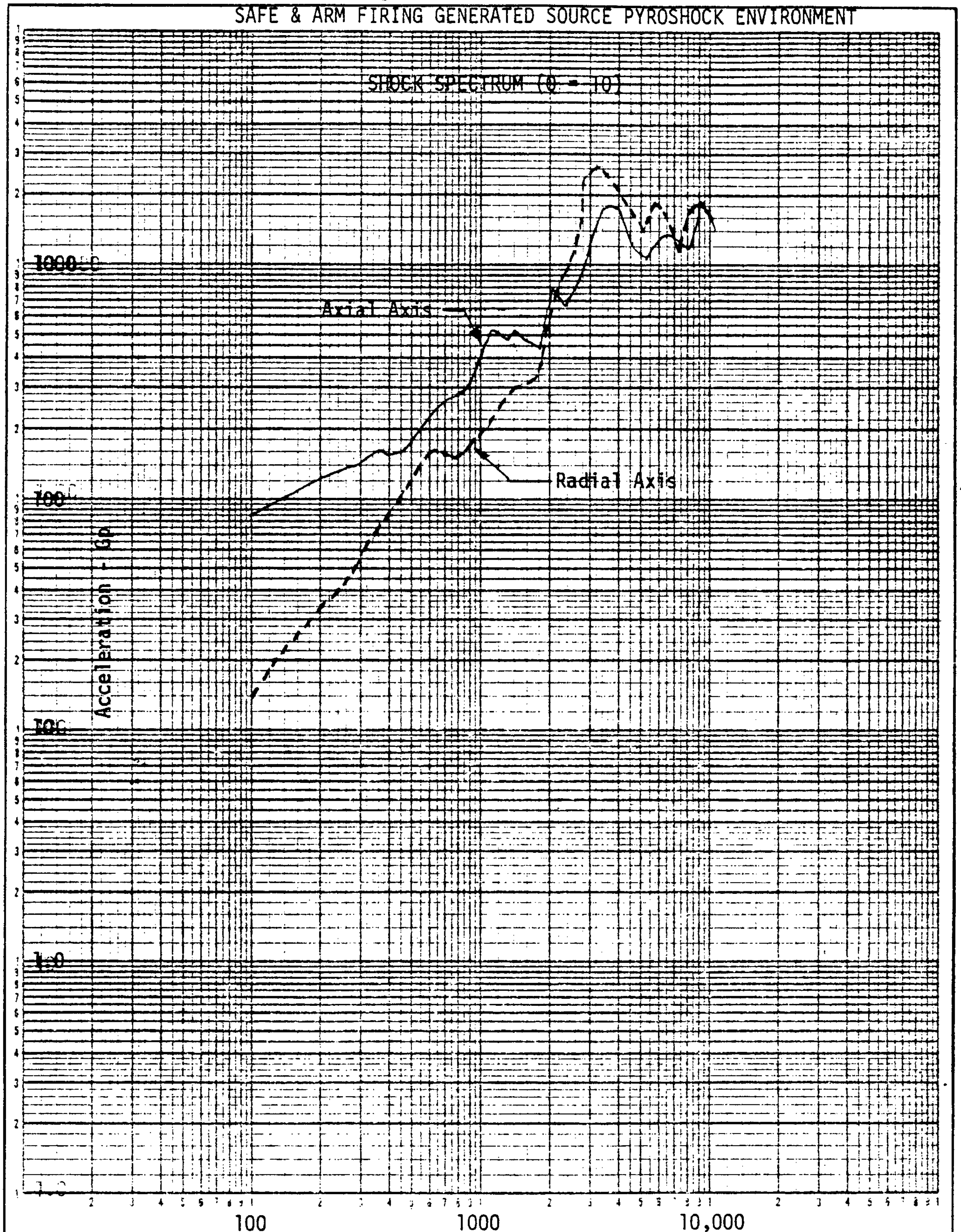
Figure 3.1.2.1-3

COMPARISON OF STAGE I FTS CQT REQUIREMENTS WITH ENVIRONMENTS



1/11/81

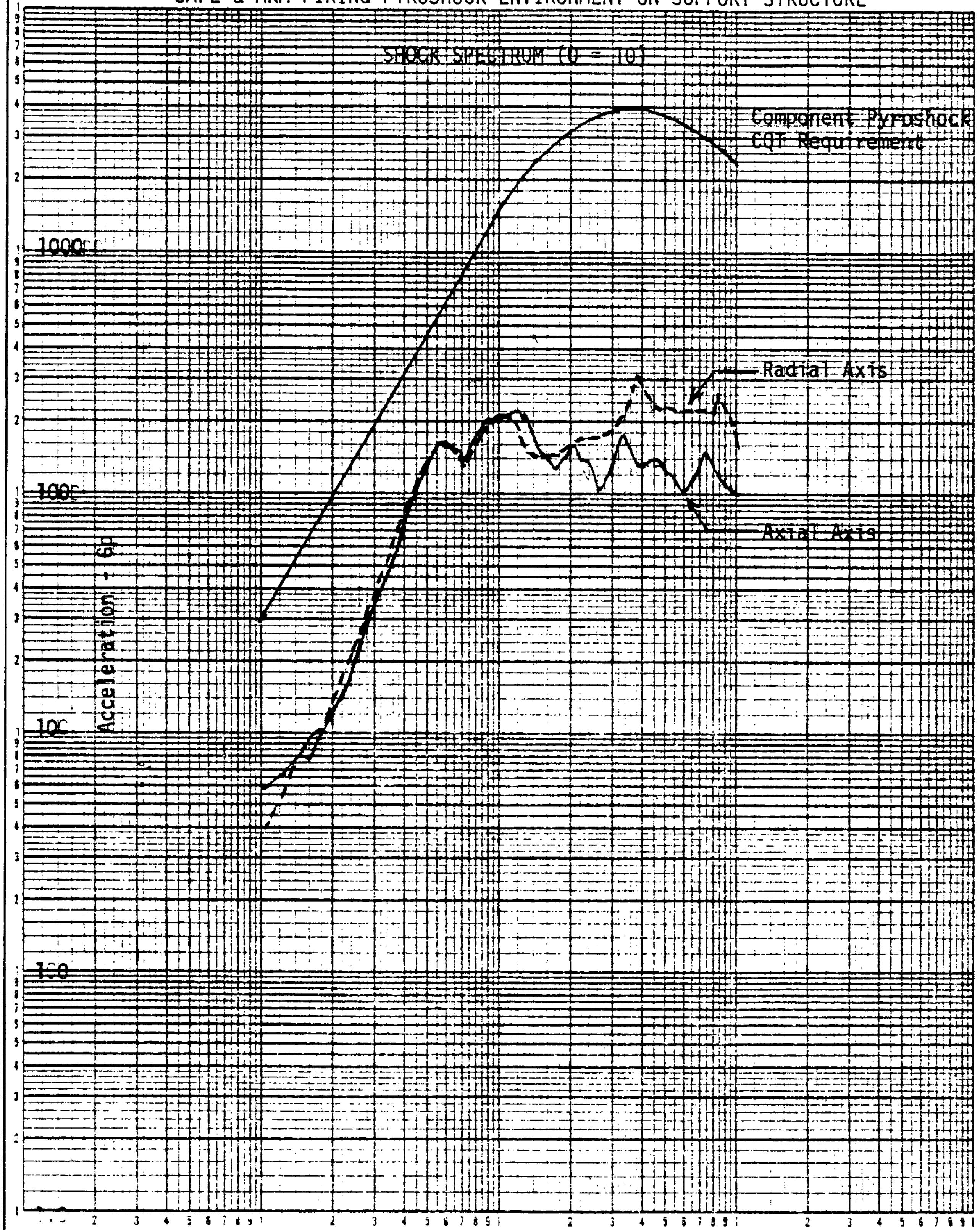
Figure 3.1.3-1
SAFE & ARM FIRING GENERATED SOURCE PYROSHOCK ENVIRONMENT



1/12/81

Figure 3.1.3-2

SAFE & ARM FIRING PYROSHOCK ENVIRONMENT ON SUPPORT STRUCTURE



1/12/81

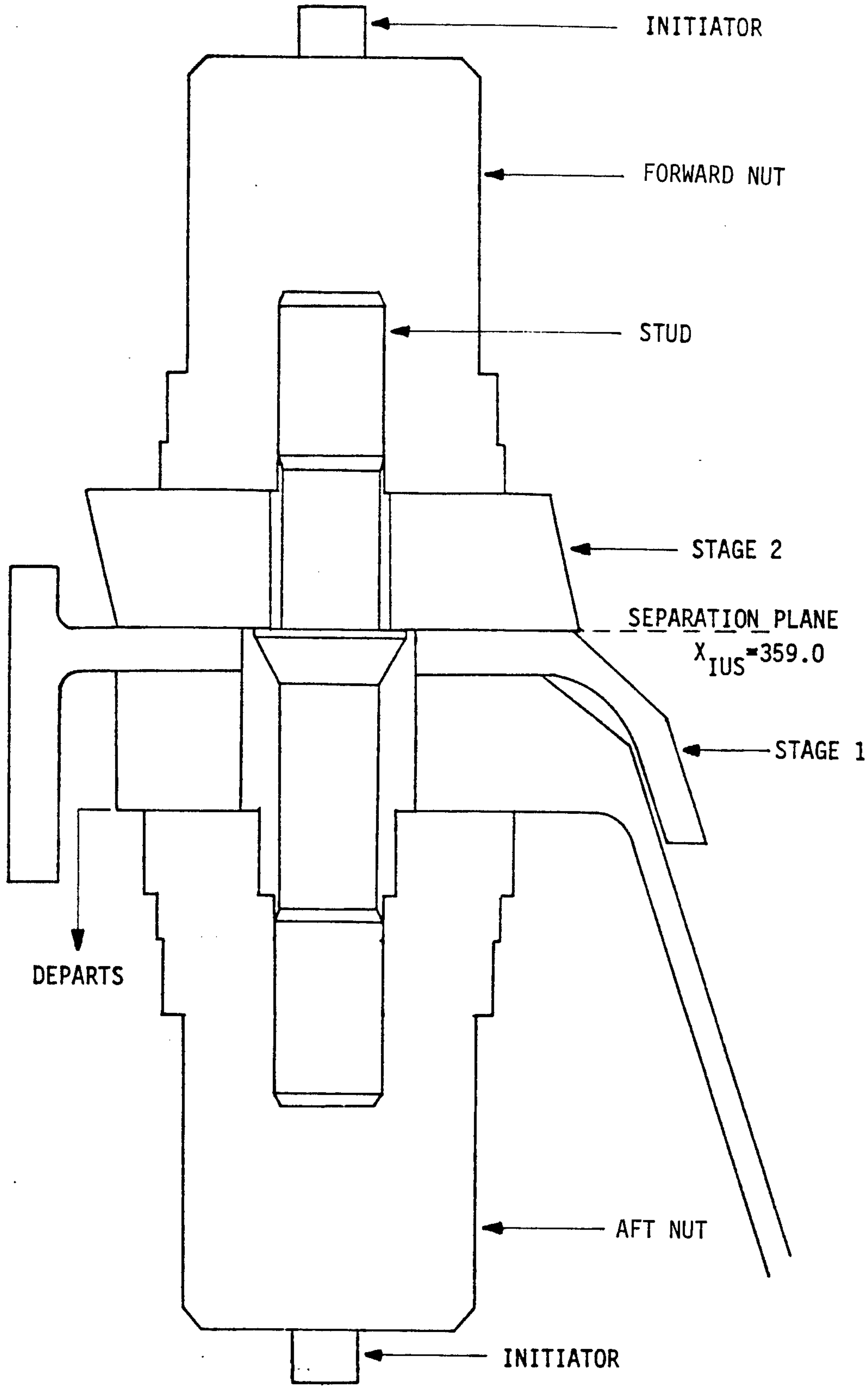
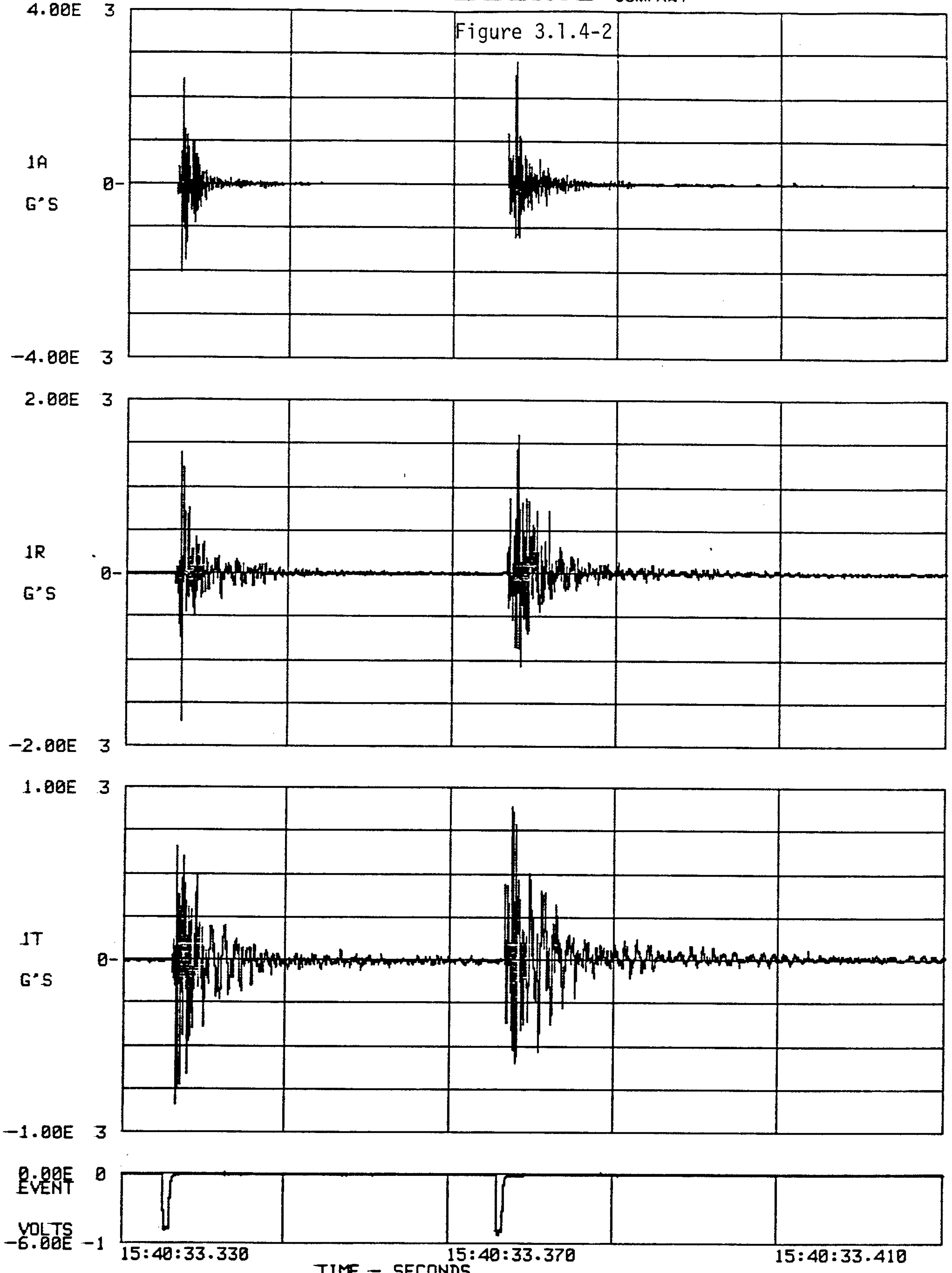


Figure 3.1.4-1 SEPARATION JOINT

THE BOEING COMPANY

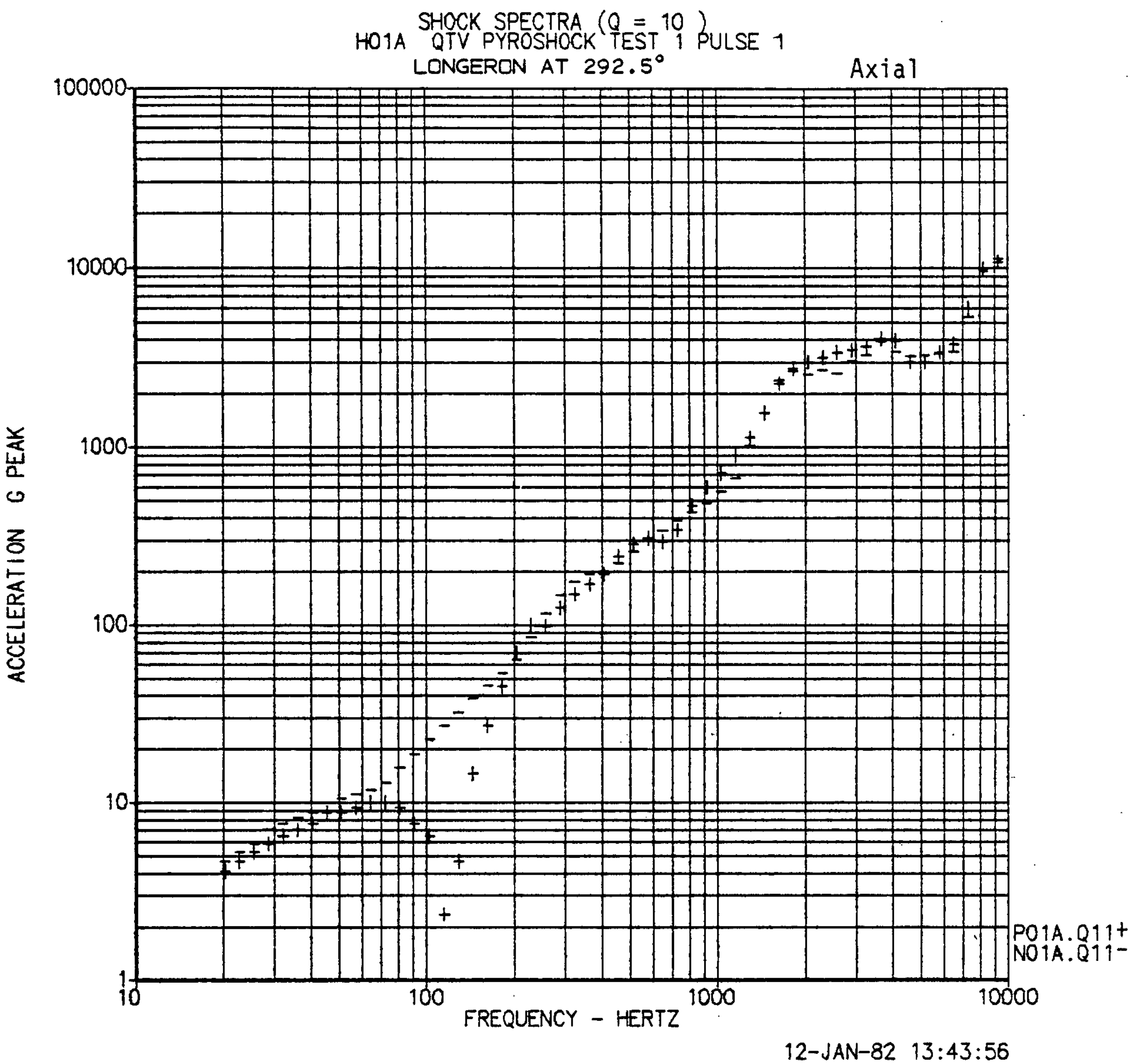
Figure 3.1.4-2



8593 A266

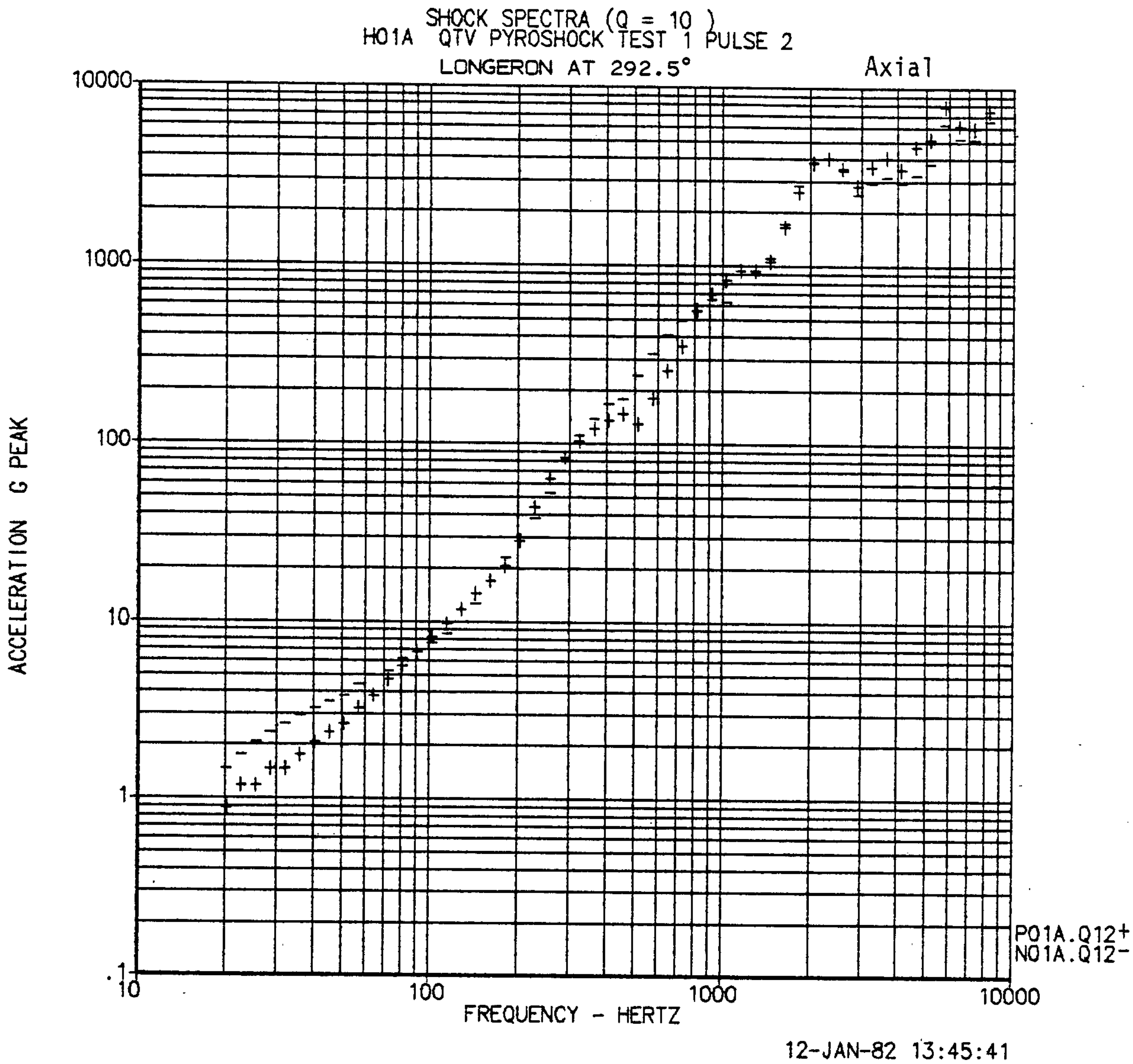
CALC	MJC 5/15/81		IUS QTV PYRO-SHOCK (S&A'S INSTALLED) SEPARATION TEST NO 1 SEPARATION EVENT SOURCE SHOCK APPROX. 4" FORWARD OF SEPARATION NUT ON 292.5° LONGERON
CHECK			
APPD			
APPD			

Figure 3.1.4-3



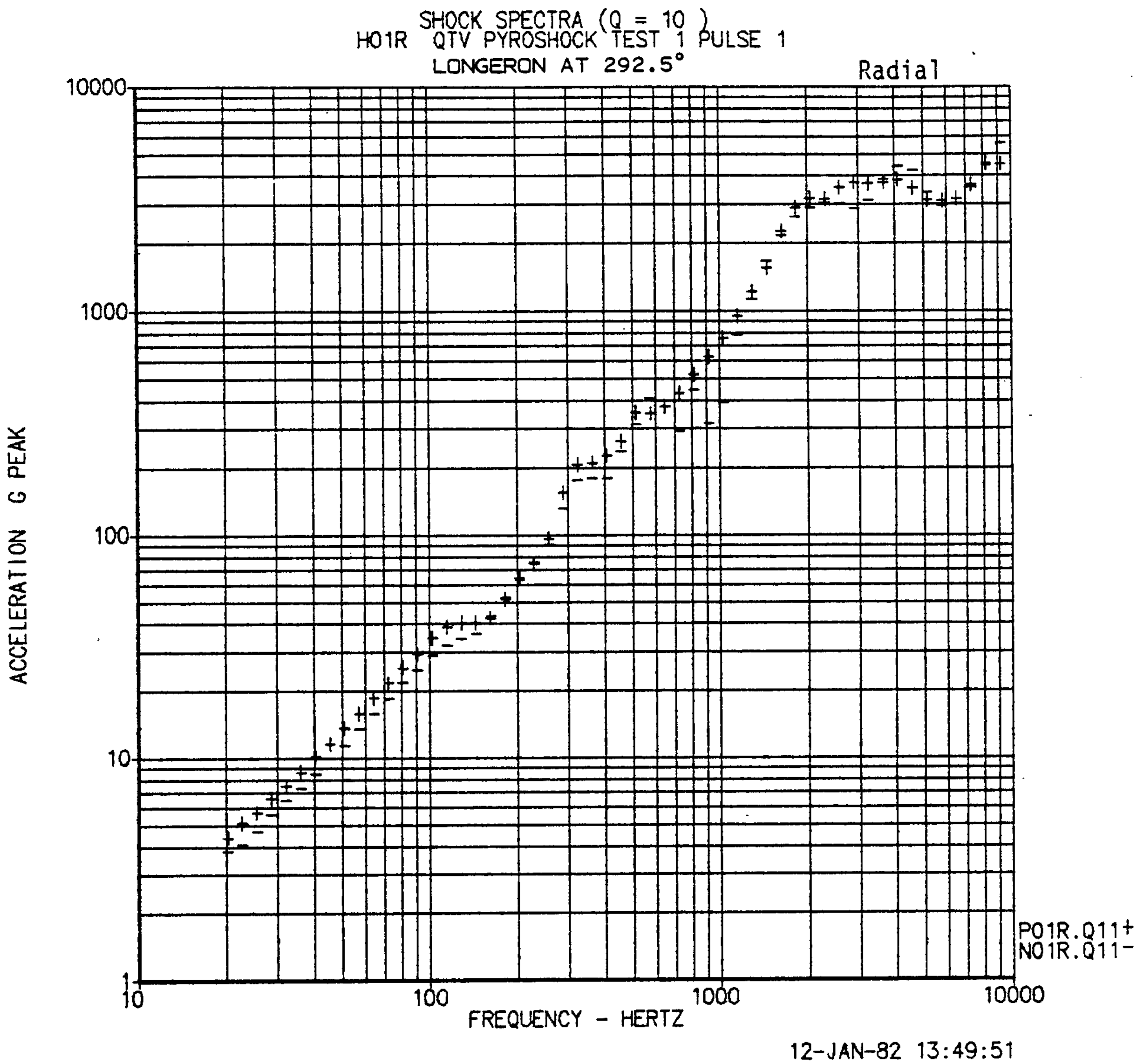
CALC		12JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment
CHECK					
APPD.					
APPD.					THE BOEING COMPANY

Figure 3.1.4-4



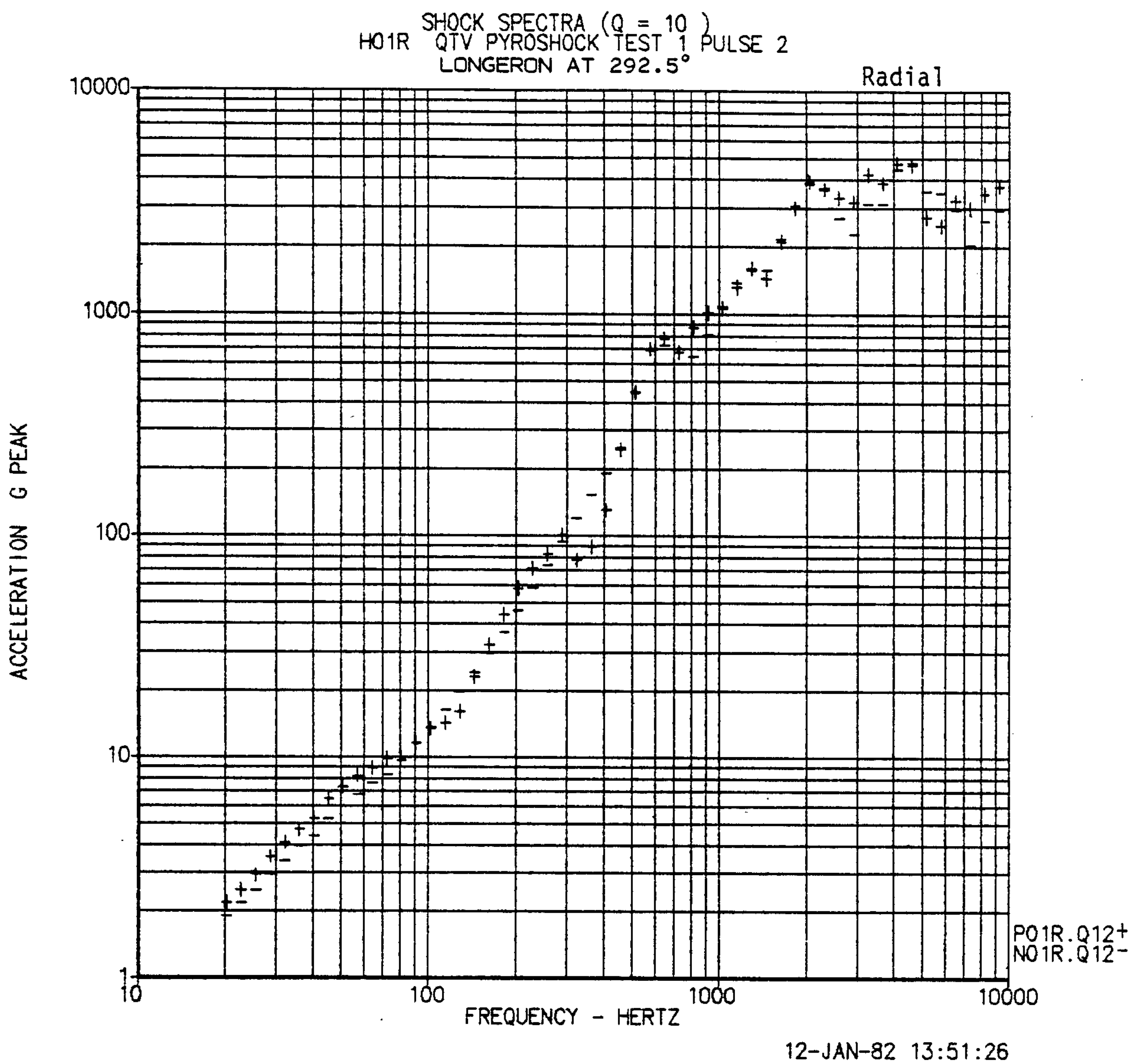
CALC		12JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE 69

Figure 3.1.4-5



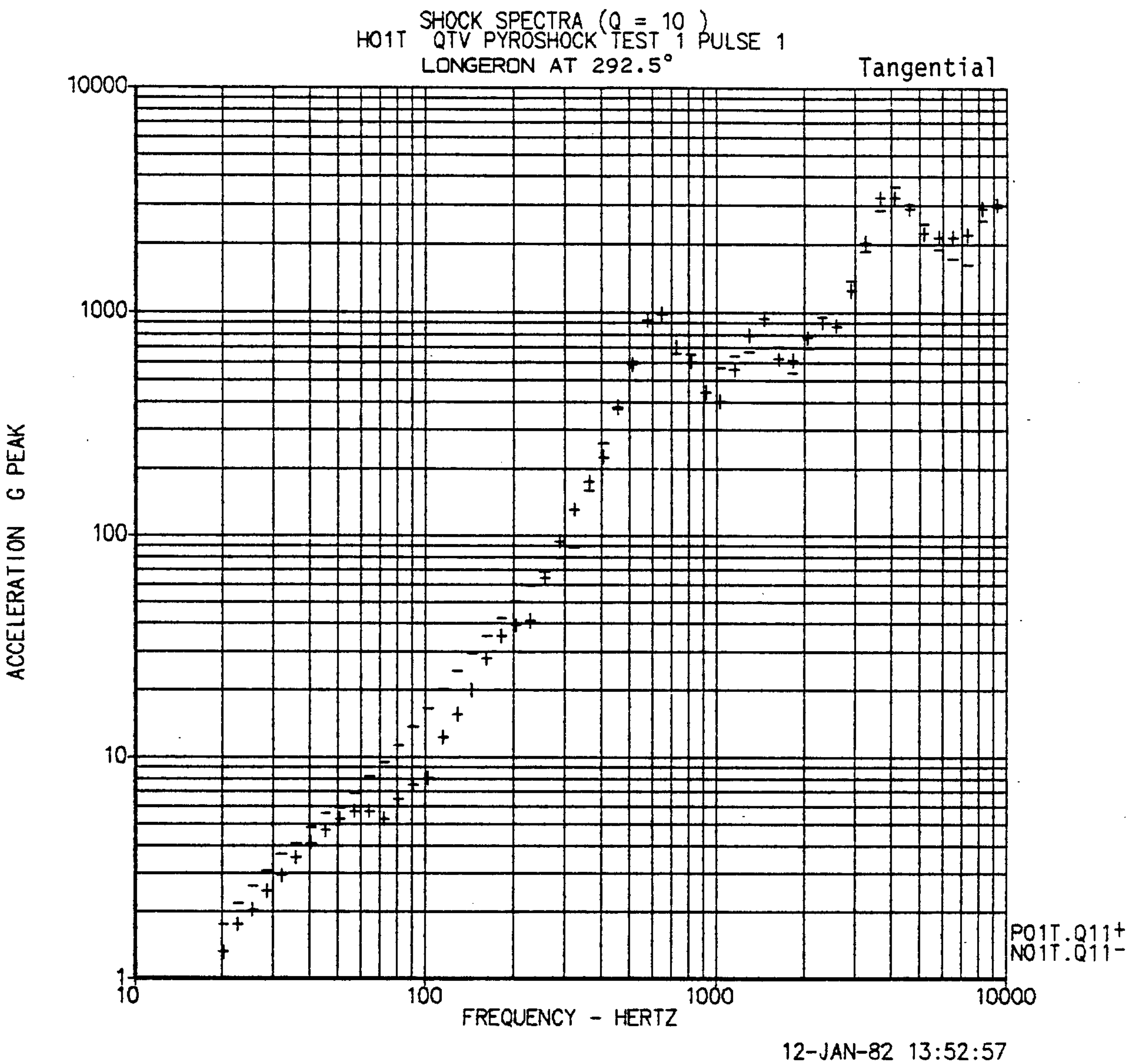
CALC		12JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment
CHECK					
APPD.					THE BOEING COMPANY
APPD.					PAGE 70

Figure 3.1.4-6



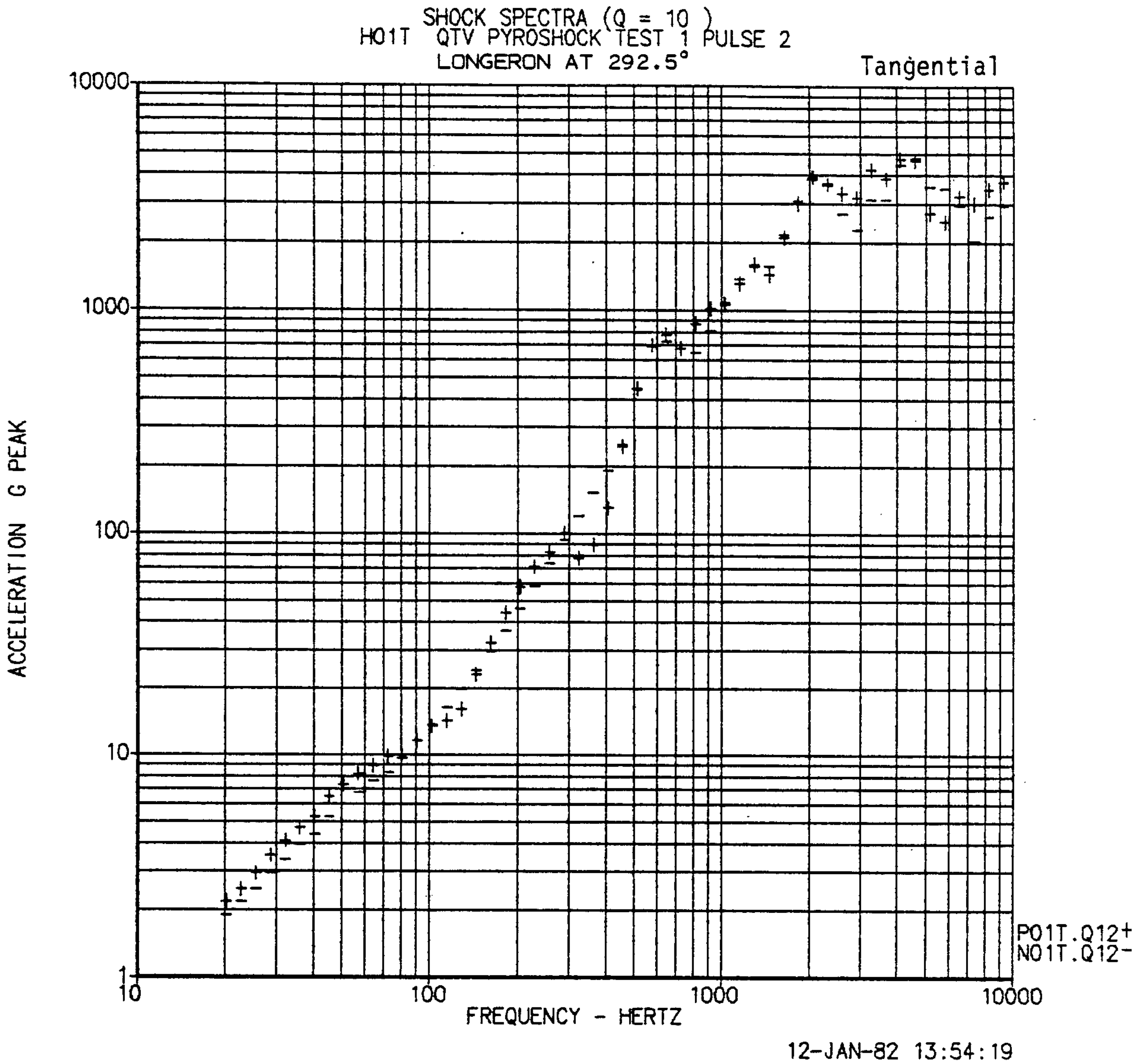
CALC		12JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE 71

Figure 3.1.4-7



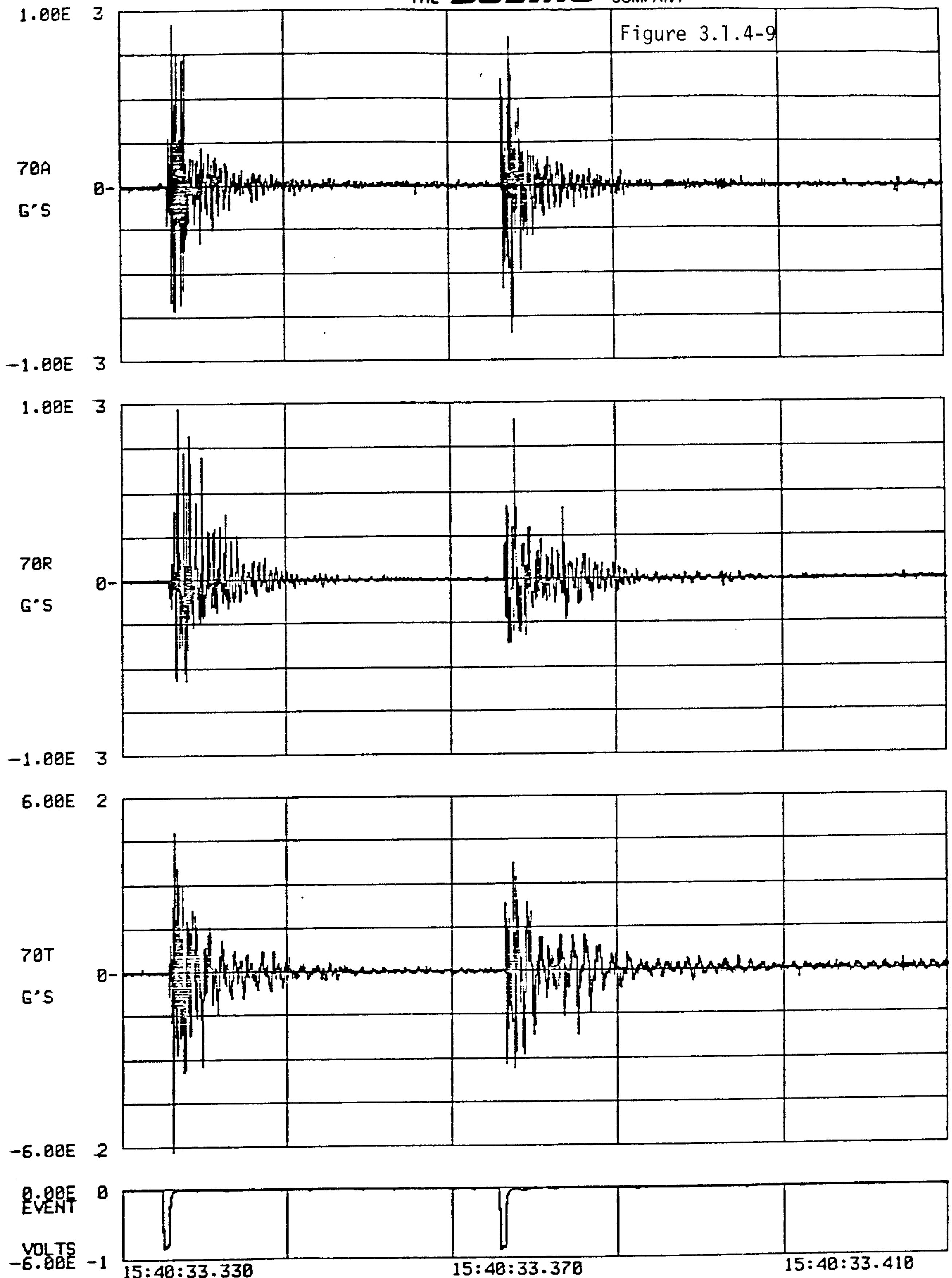
CALC		12JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE 72

Figure 3.1.4-8



CALC		12JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment
CHECK					
APPD.					
APPD.					THE BOEING COMPANY
					PAGE 73

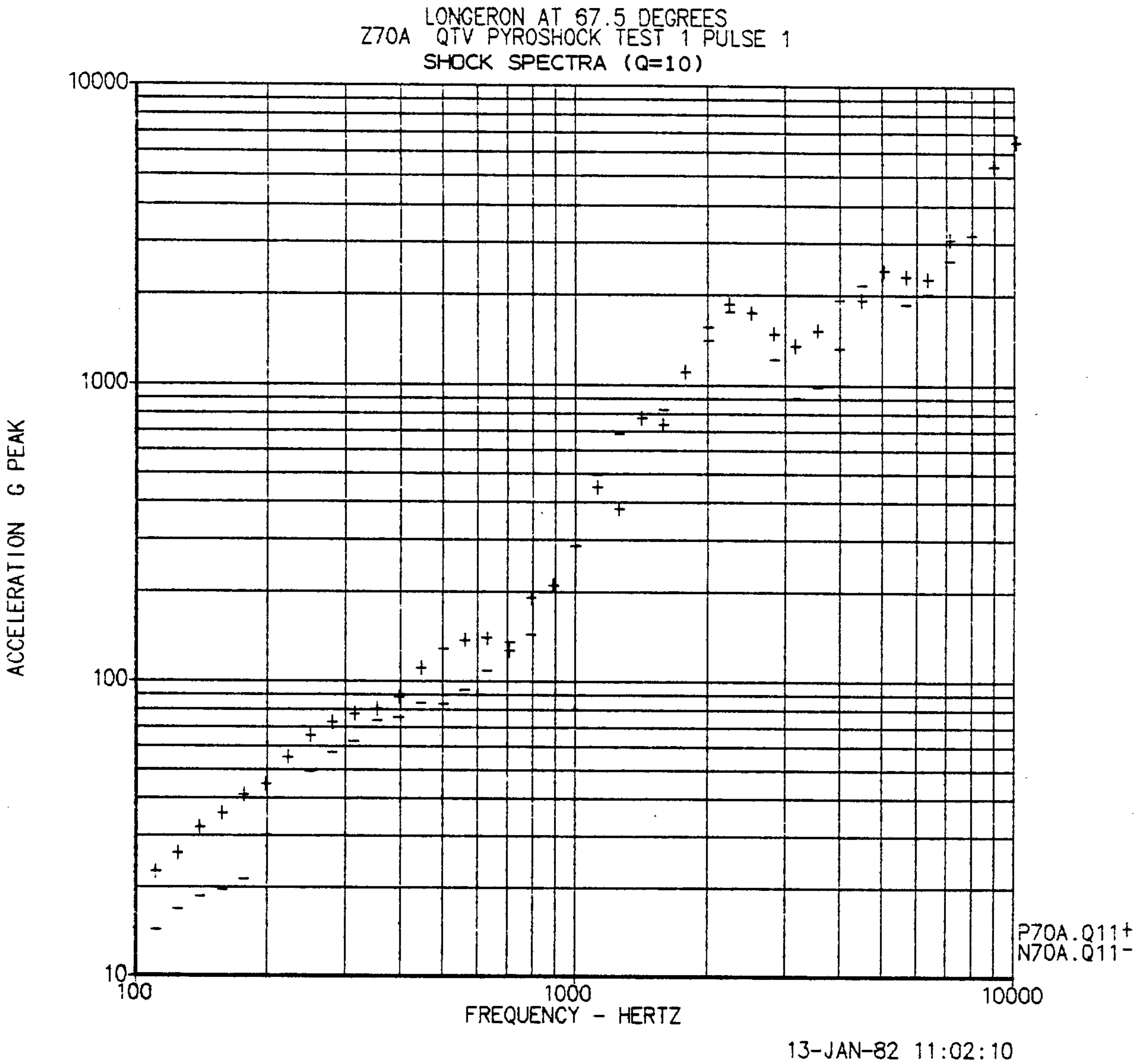
THE BOEING COMPANY



8593 A274

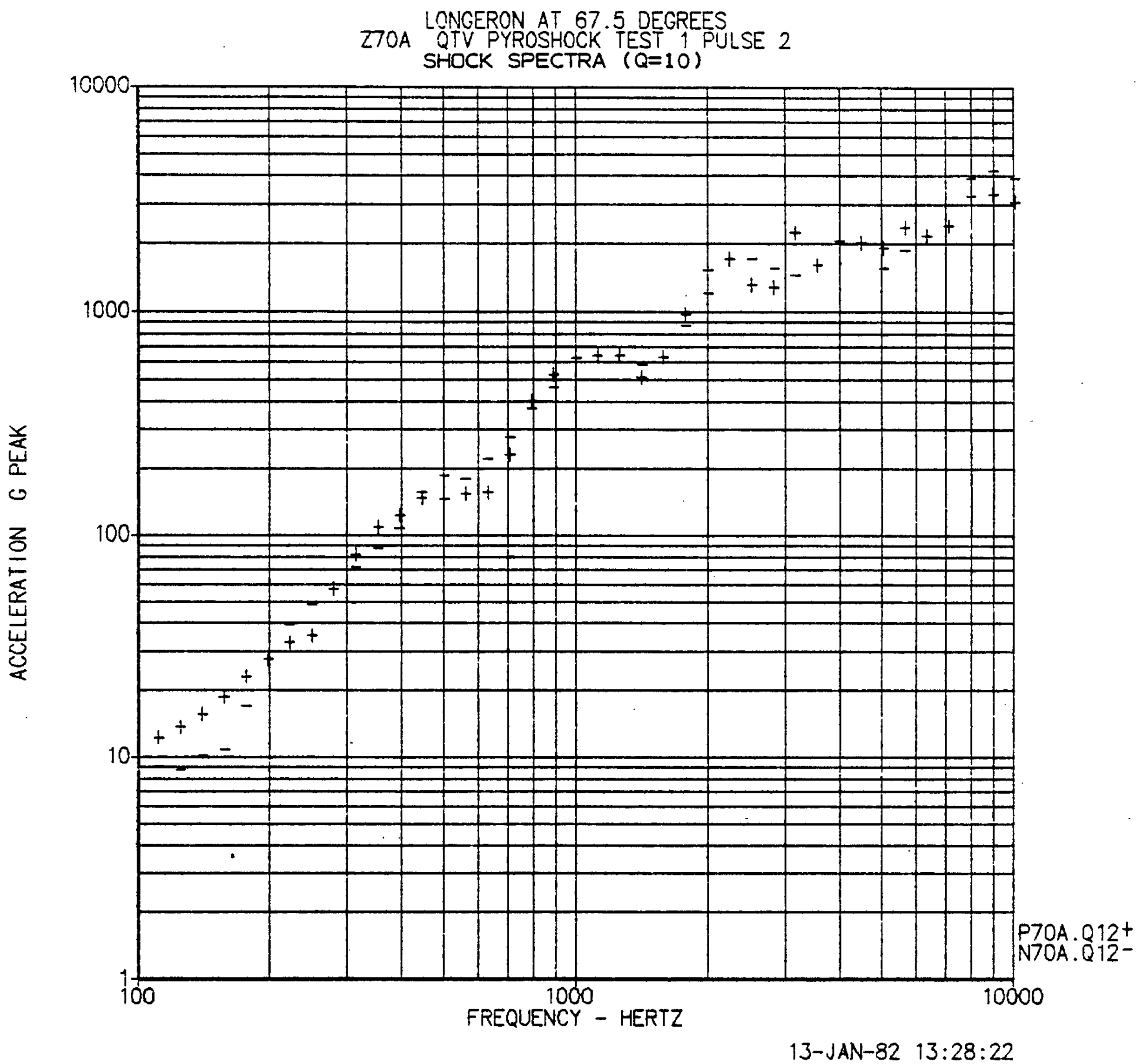
CALC	MJC 5/17/81		IUS QTV PYRO-SHOCK (S&A'S INSTALLED)
CHECK			SEPARATION TEST NO 1
APPD			SEPARATION EVENT SOURCE SHOCK APPROX. 4" FORWARD OF
APPD			SEPARATION NUT ON 67.5° LONGERON

Figure 3.1.4-10



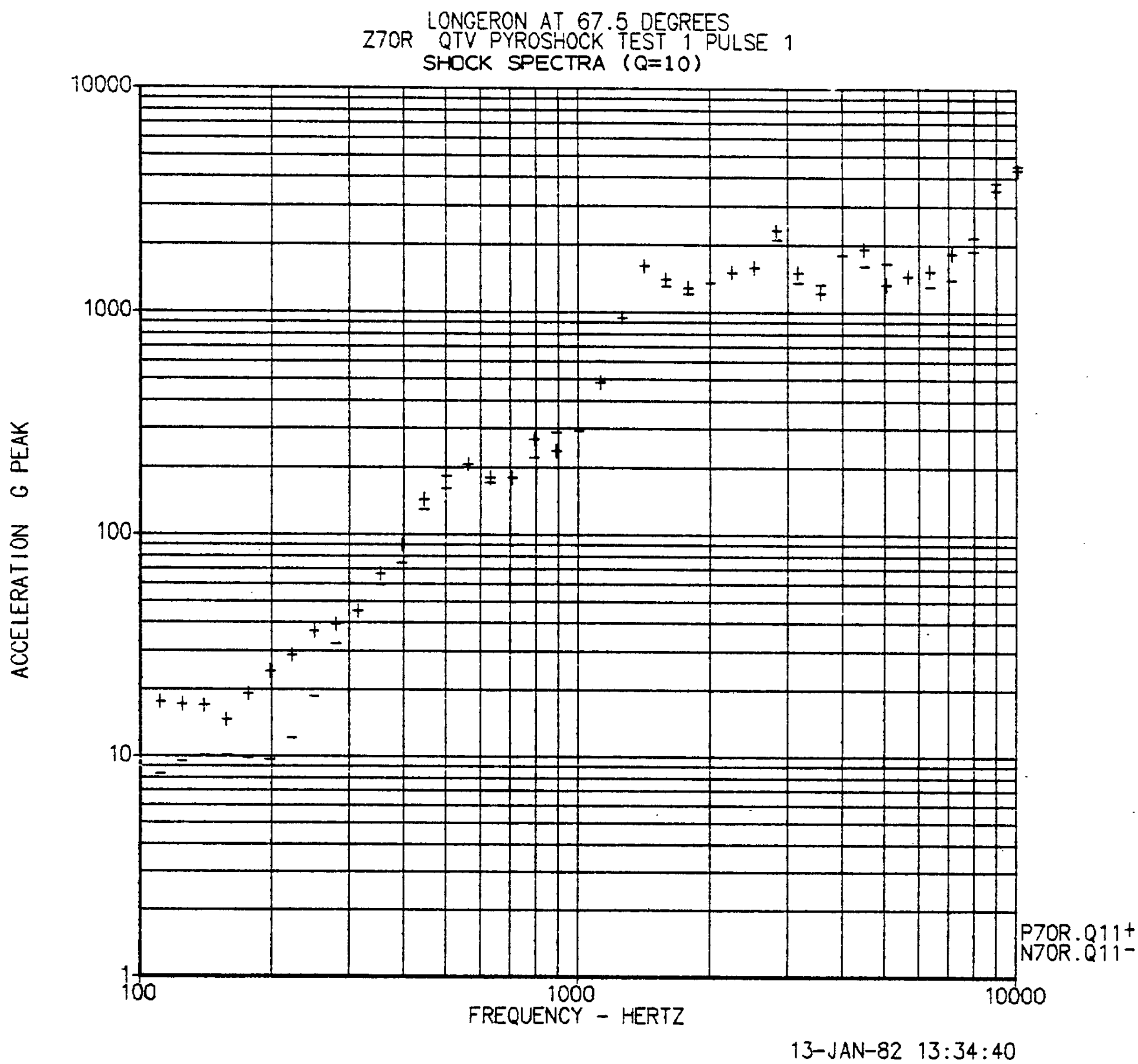
CALC		13JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
CHECK						
APPD.					THE BOEING COMPANY	PAGE 75
APPD.						

Figure 3.1.4-11



CALC		13JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment		
CHECK							
APPD.							
APPD.					THE BOEING COMPANY	PAGE 76	

Figure 3.1.4-12



CALC		13JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE 77

Figure 3.1.4-13

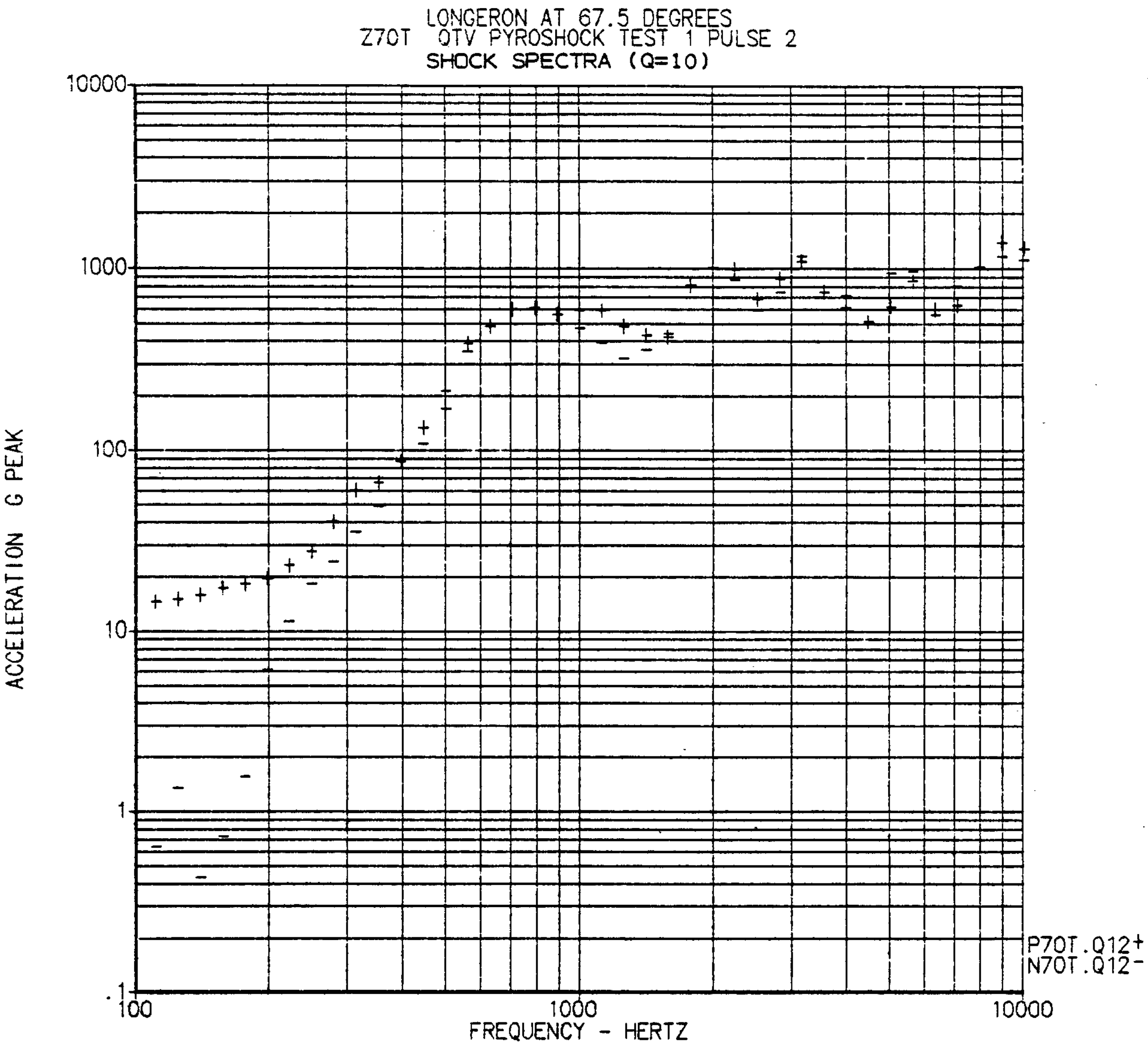


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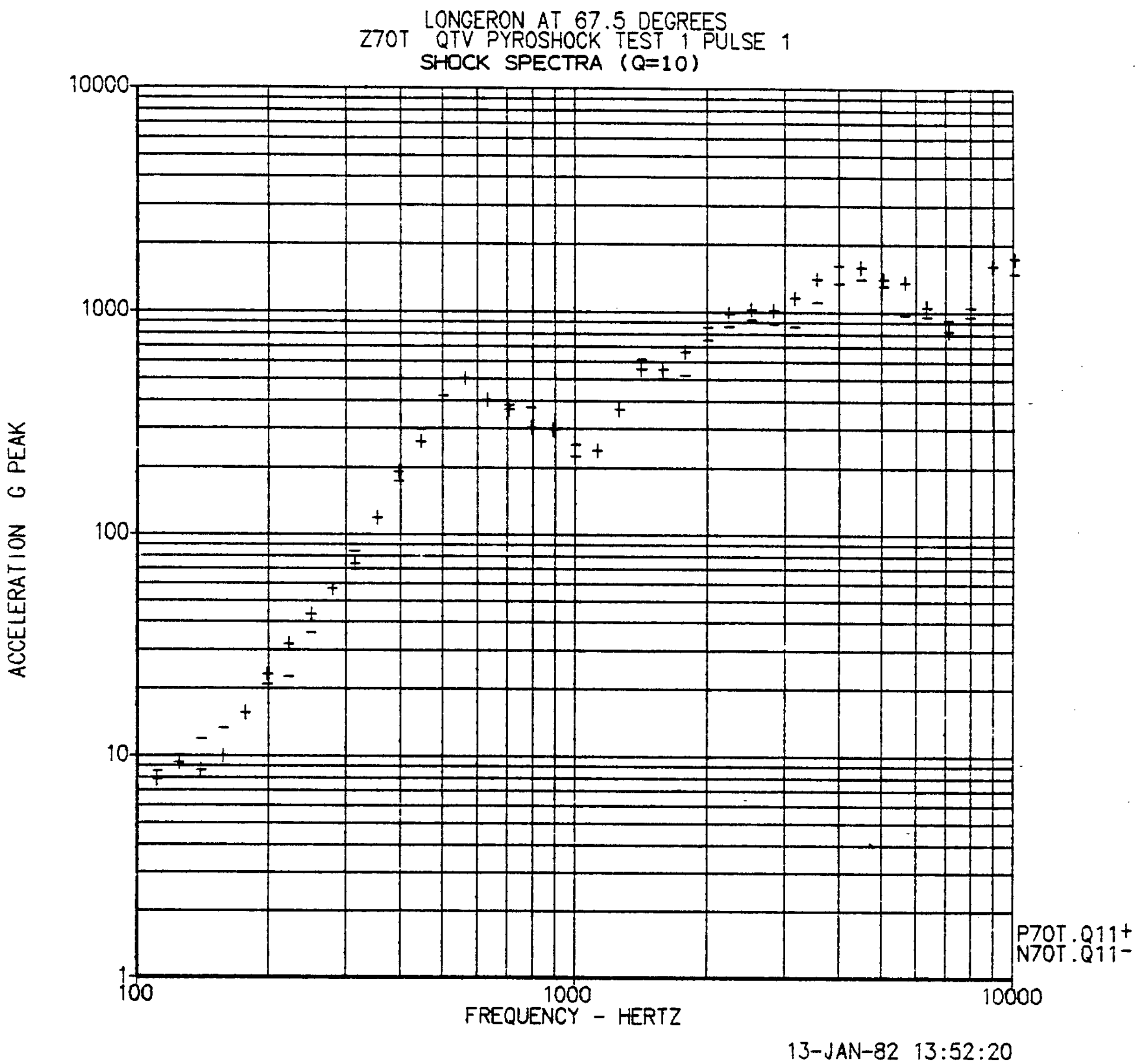
Figure 3.1.4-14



CALC		13JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
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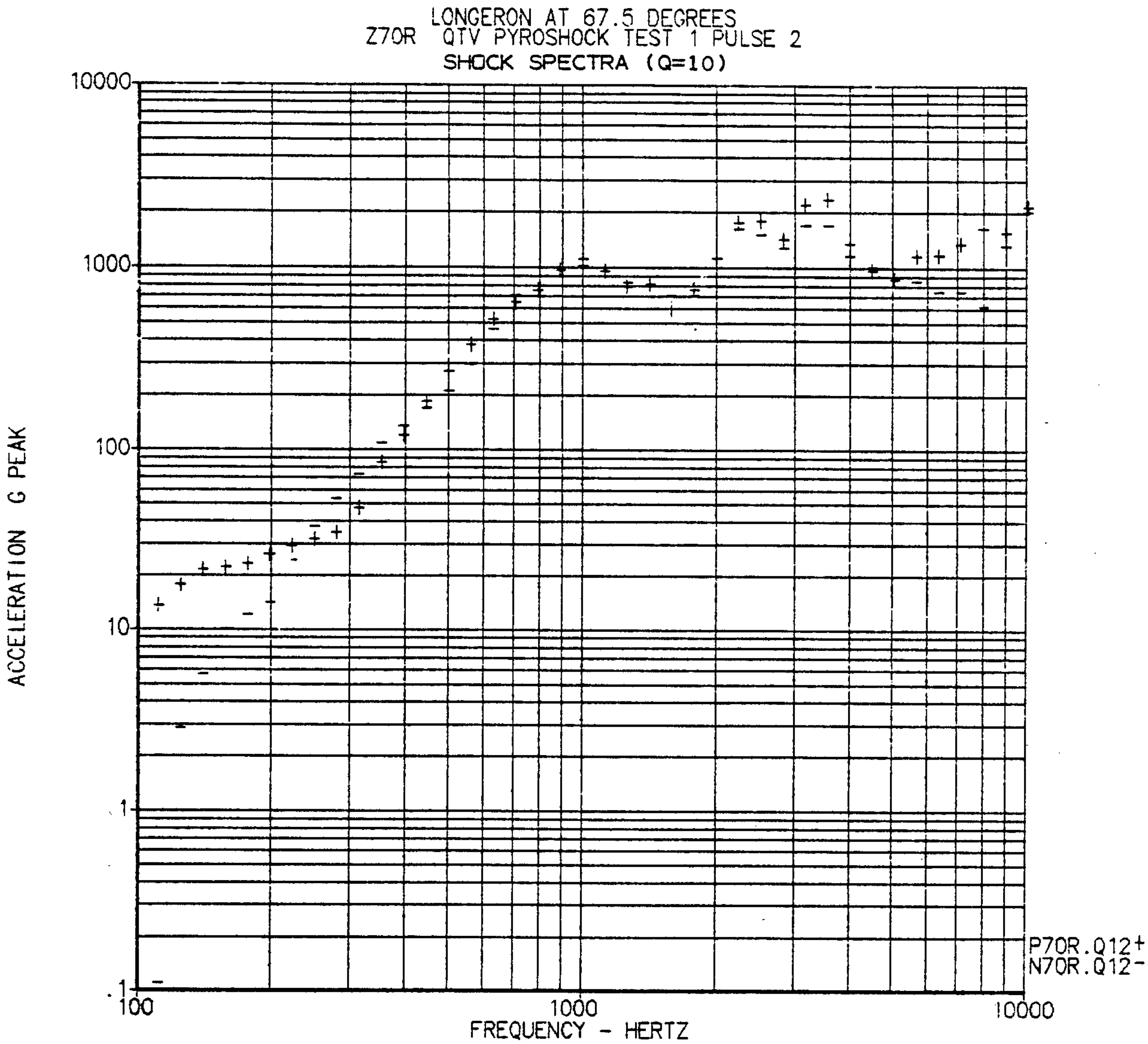
Figure 3.1.4-15



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CALC		13JAN82	REVISED	DATE	Stage I/Stage II Separation Source Shock Environment	
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Figure 3.1.6-1

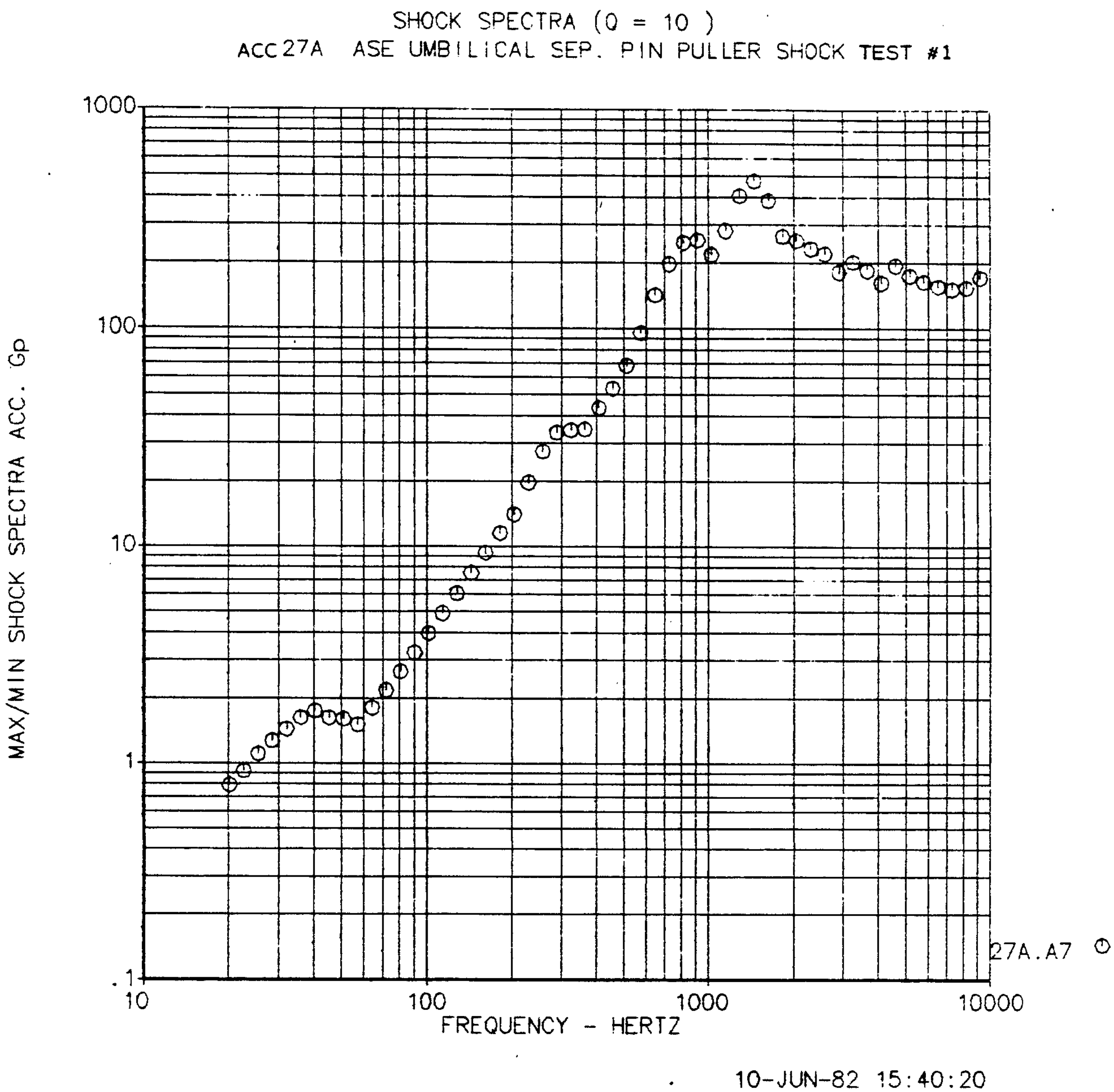

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Figure 3.1.6-2

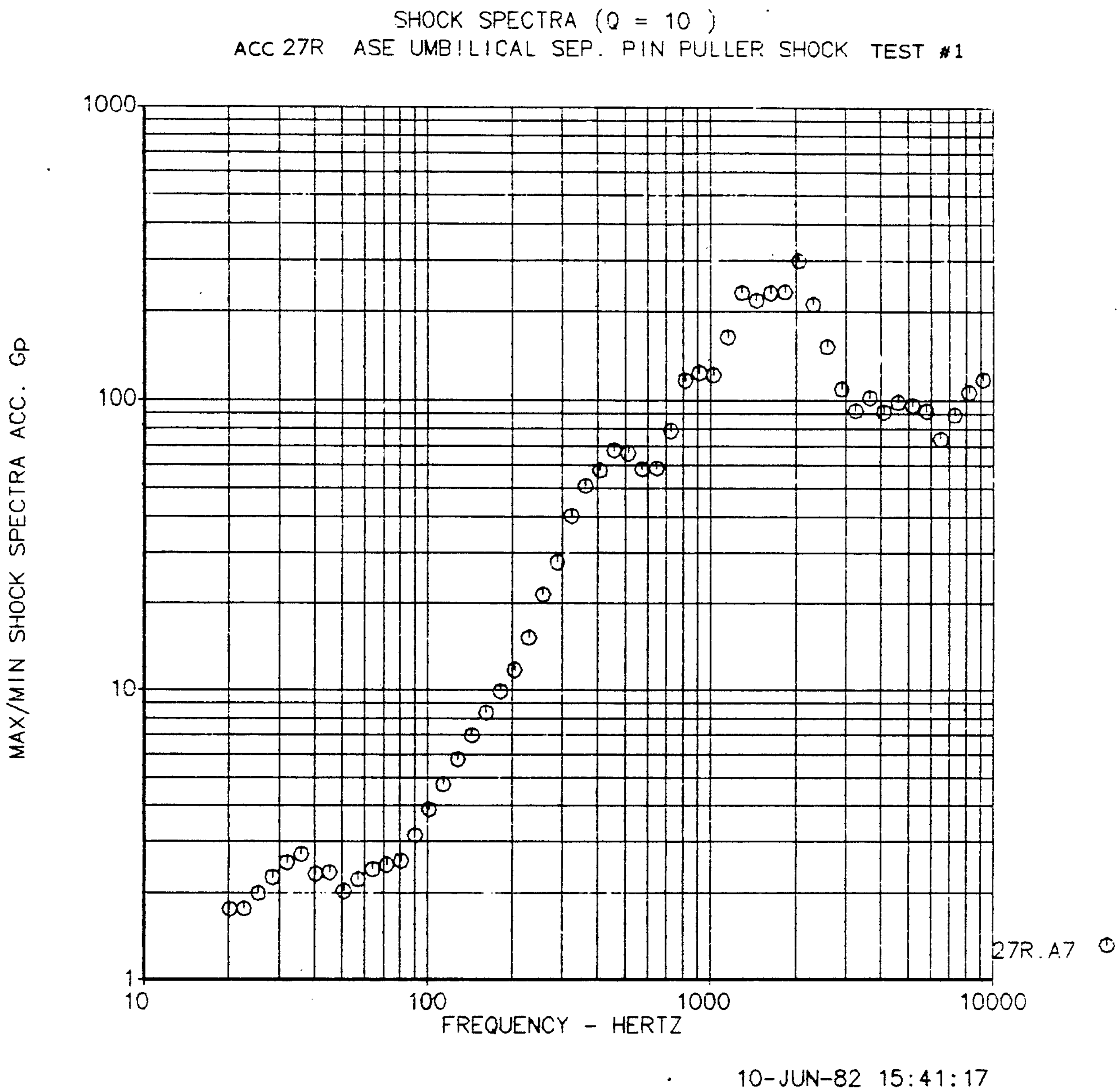
SHOCK SPECTRA (Q = 10)
ACC 27R ASE UMBILICAL SEP. PIN PULLER SHOCK TEST #1
MAX/MIN SHOCK SPECTRA ACC. Gp
1000
100
10
1
10
100
1000
10000
FREQUENCY - HERTZ
27R.A7
10-JUN-82 15:41:17

Figure 3.1.6-3

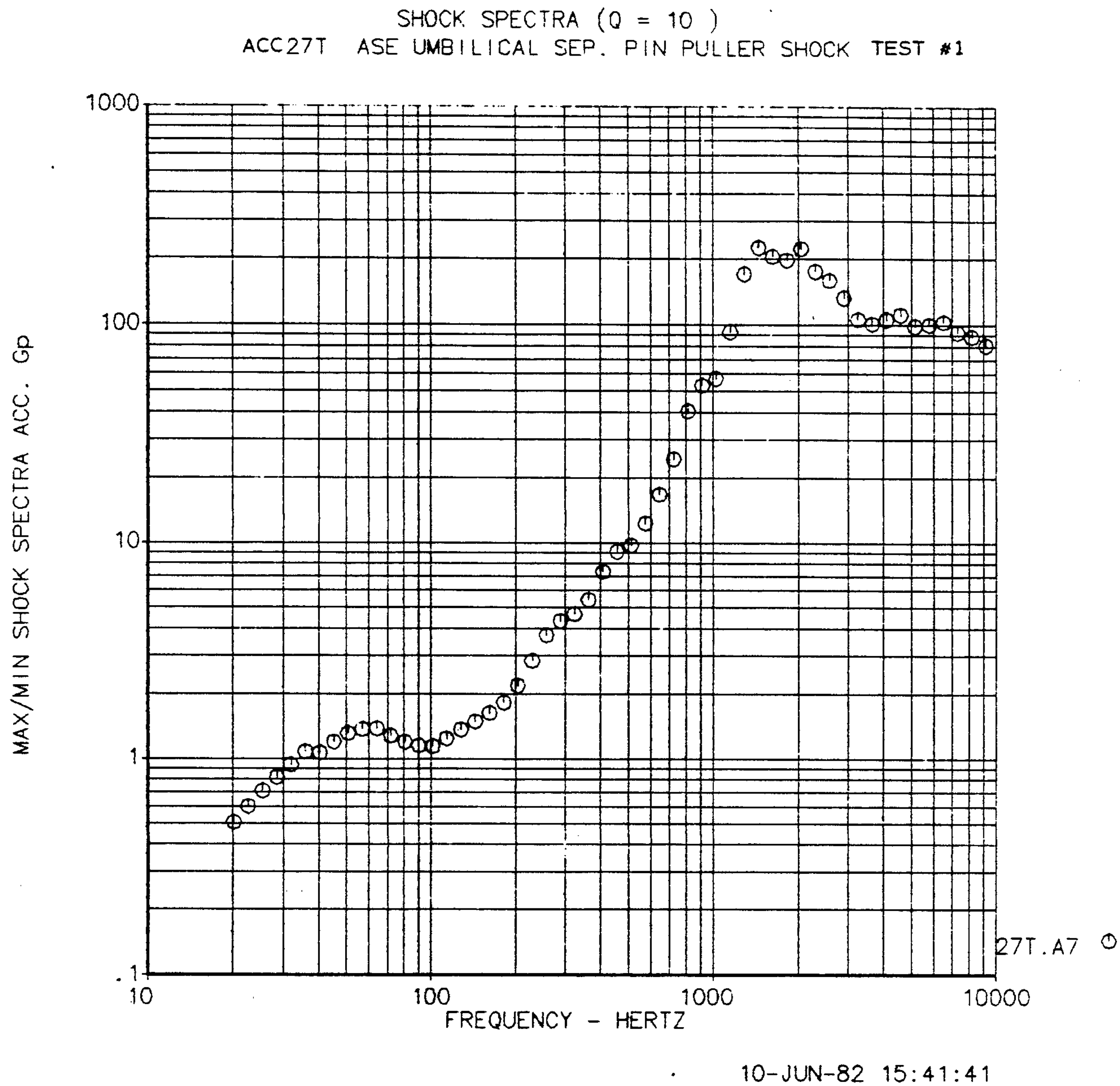

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Figure 3.1.6-4

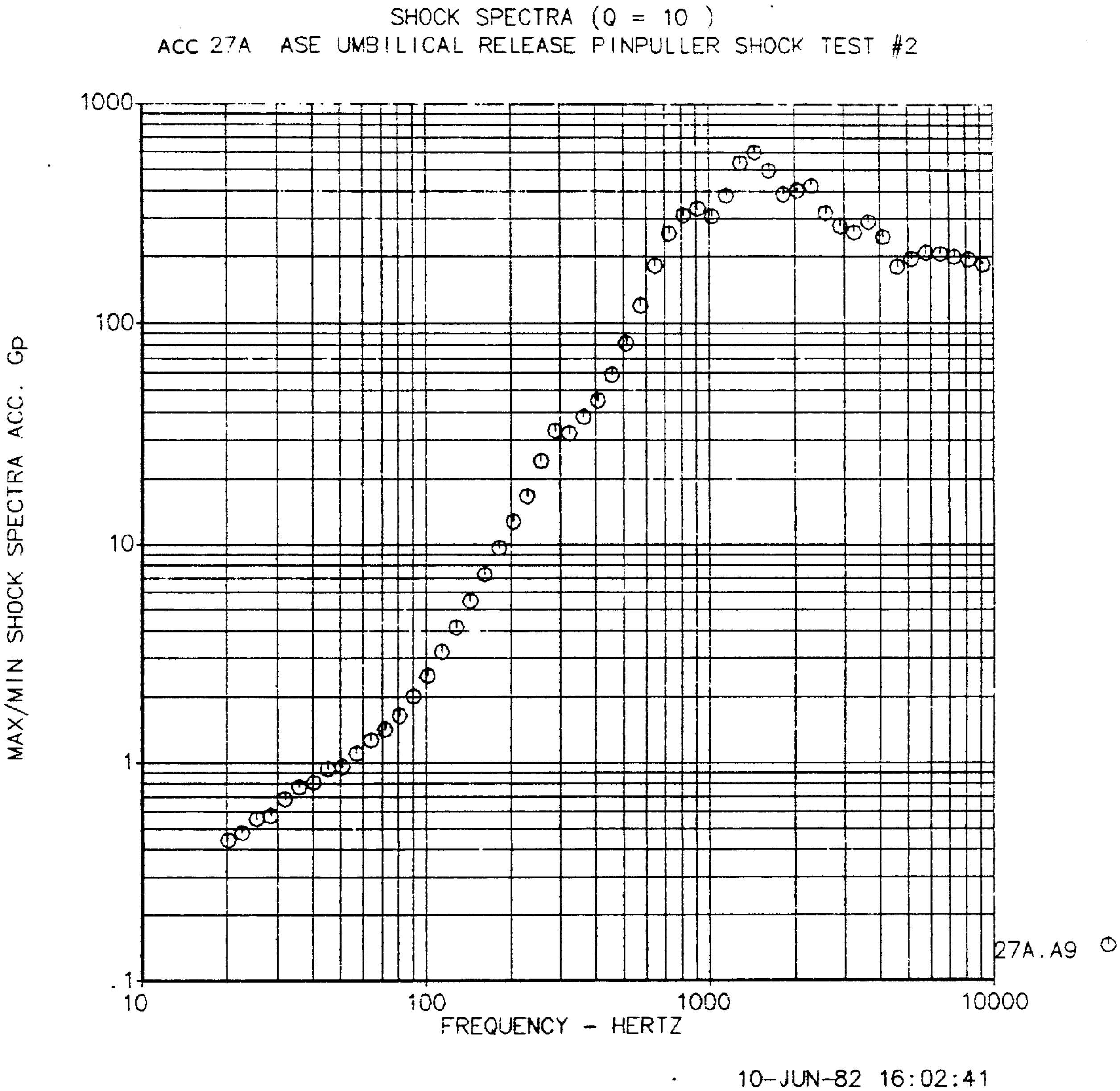

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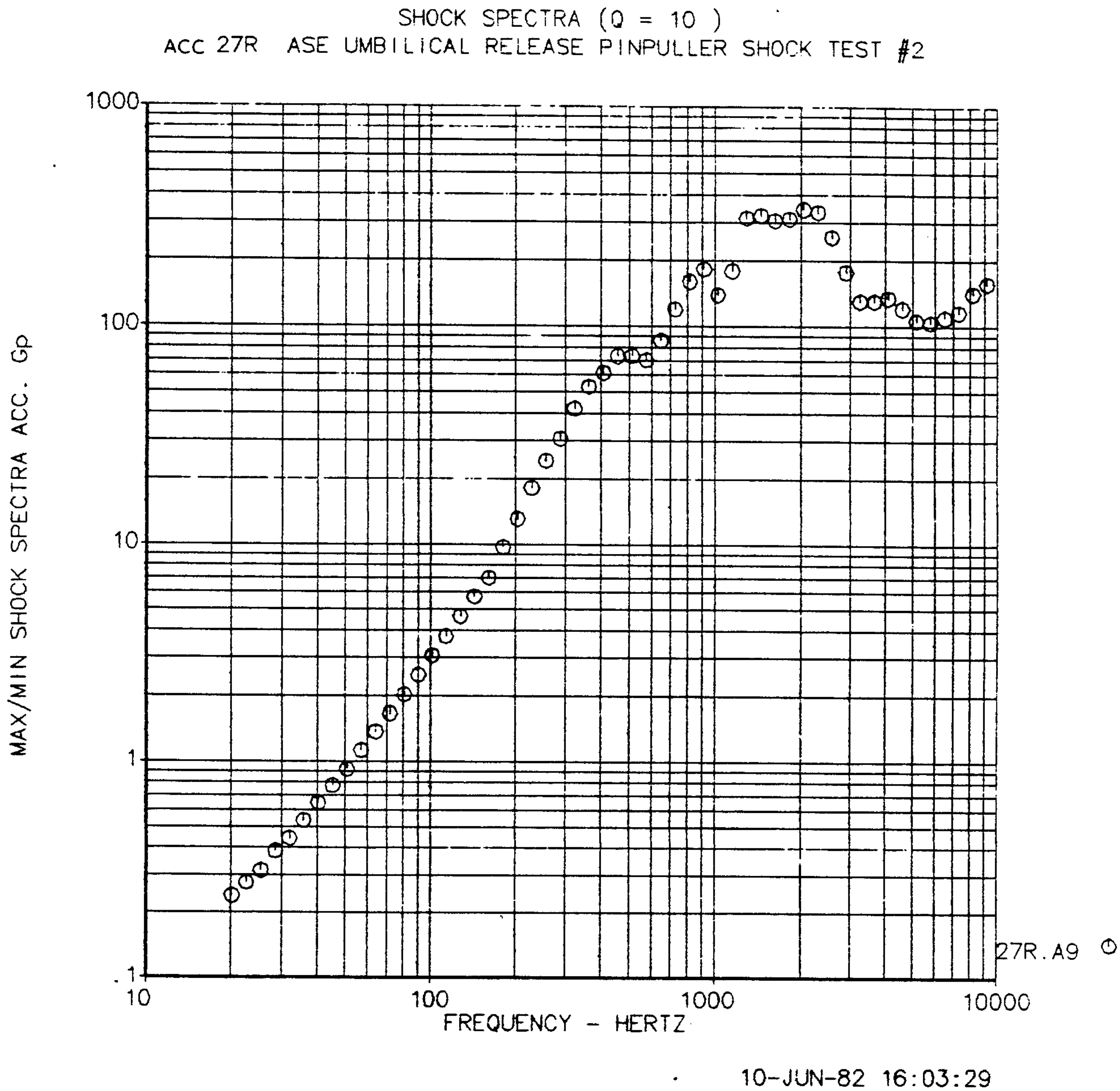
Figure 3.1.6-5



SHOCK SPECTRA (Q = 10)
ACC 27R ASE UMBILICAL RELEASE PINPULLER SHOCK TEST #2
1000
100
10
1
.1
10
100
1000
10000
FREQUENCY - HERTZ
MAX/MIN SHOCK SPECTRA ACC. Gp
27R.A9
10-JUN-82 16:03:29

Figure 3.1.6-6

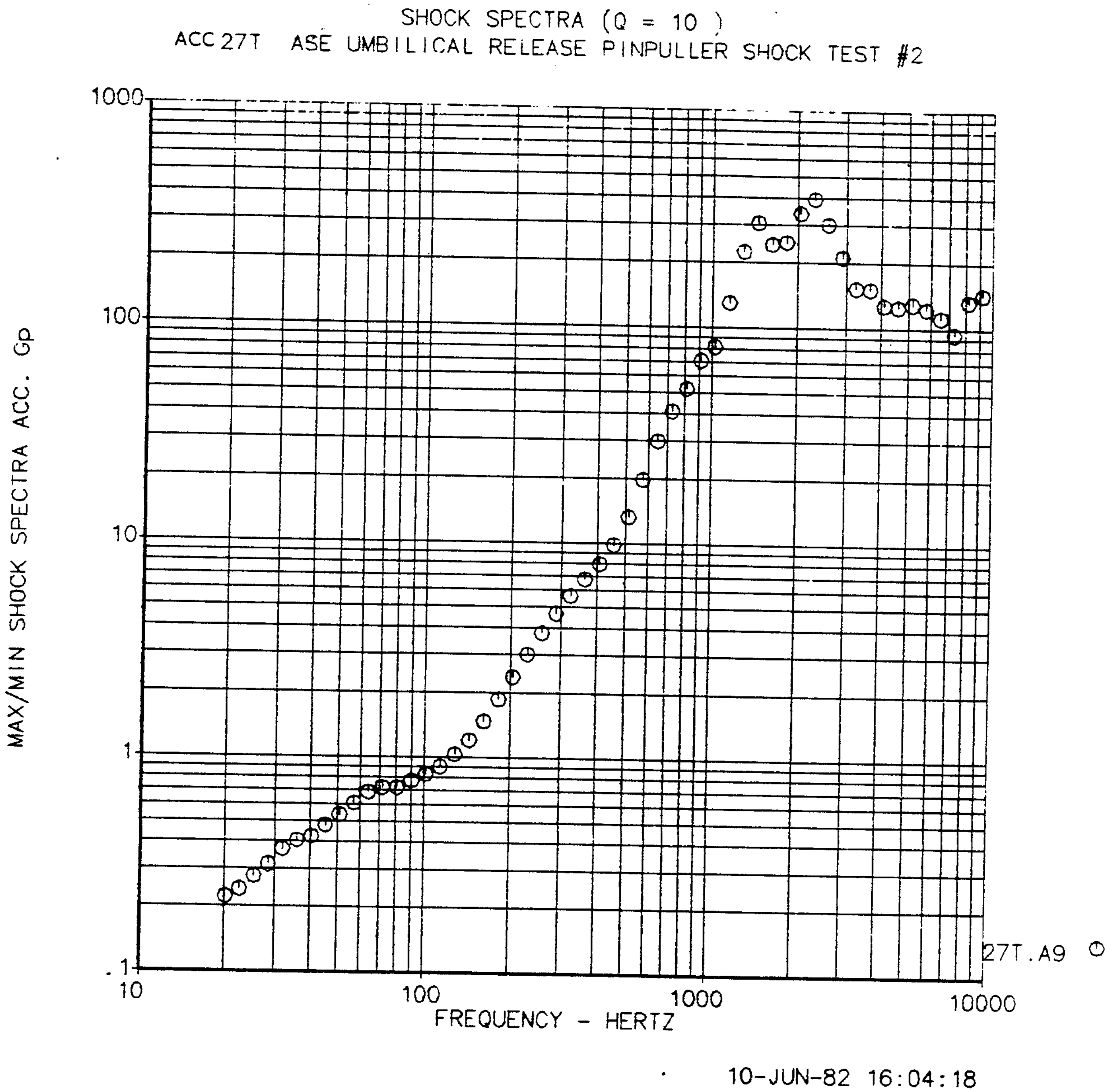


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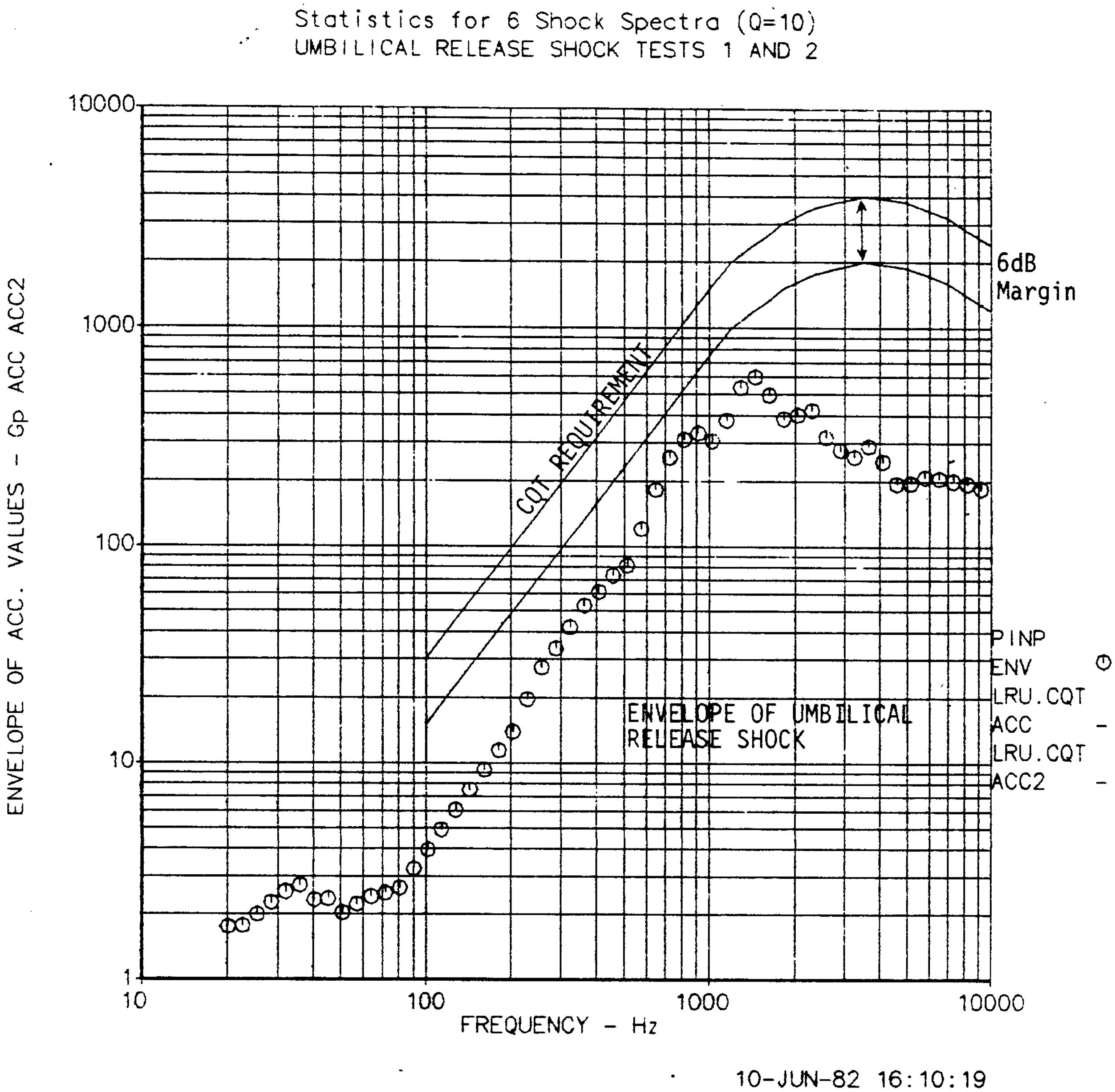
Figure 3.1.6-7



CALC		10JUN82	REVISED	DATE	COMPARISON OF UMBILICAL RELEASE SHOCK ON IUS TRUNNION RING WITH THE REM CQT REQUIREMENT	
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Figure 3.1.6-8

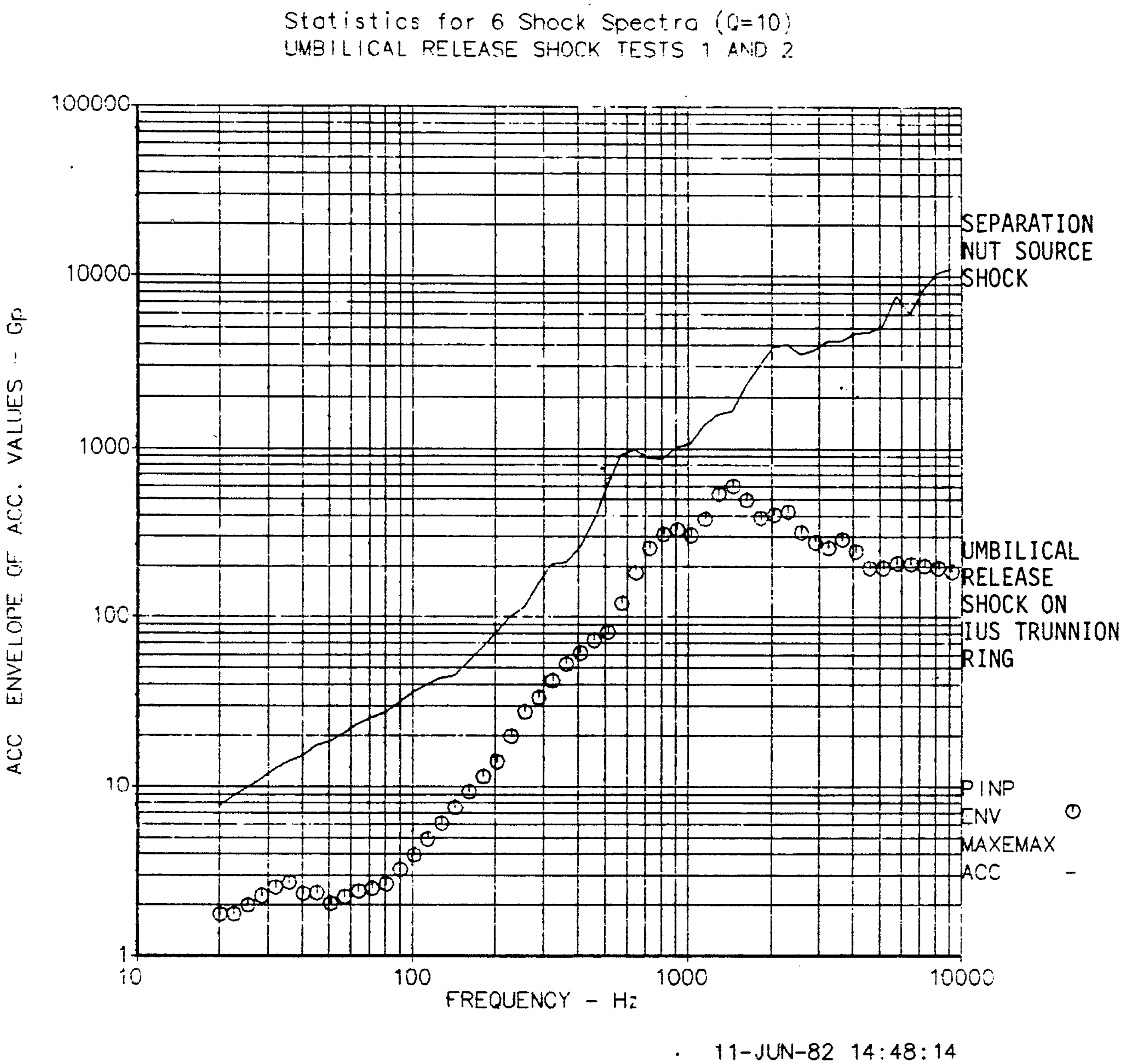

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Figure 3.3.2.1-1

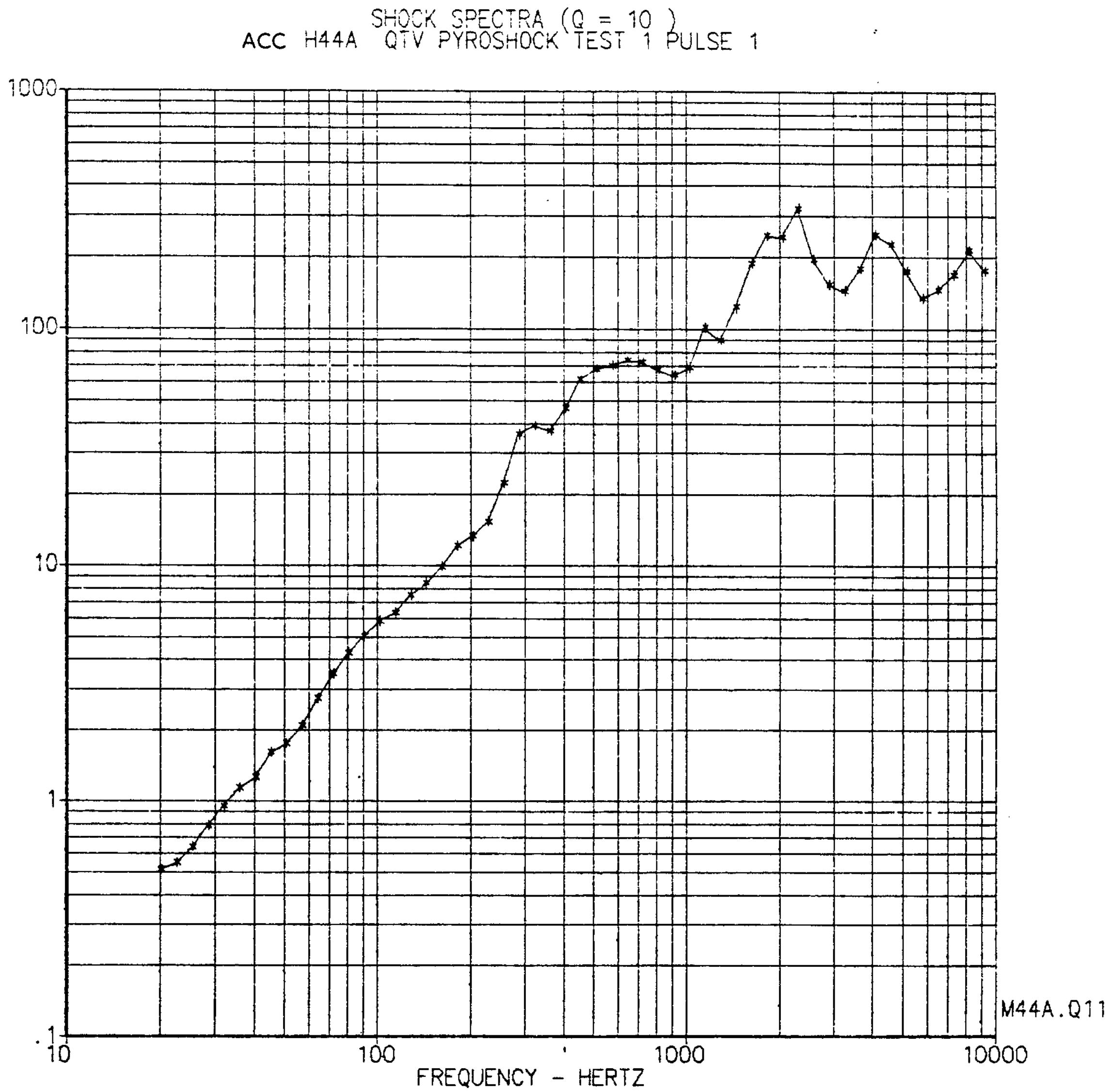

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Figure 3.3.2.1-2

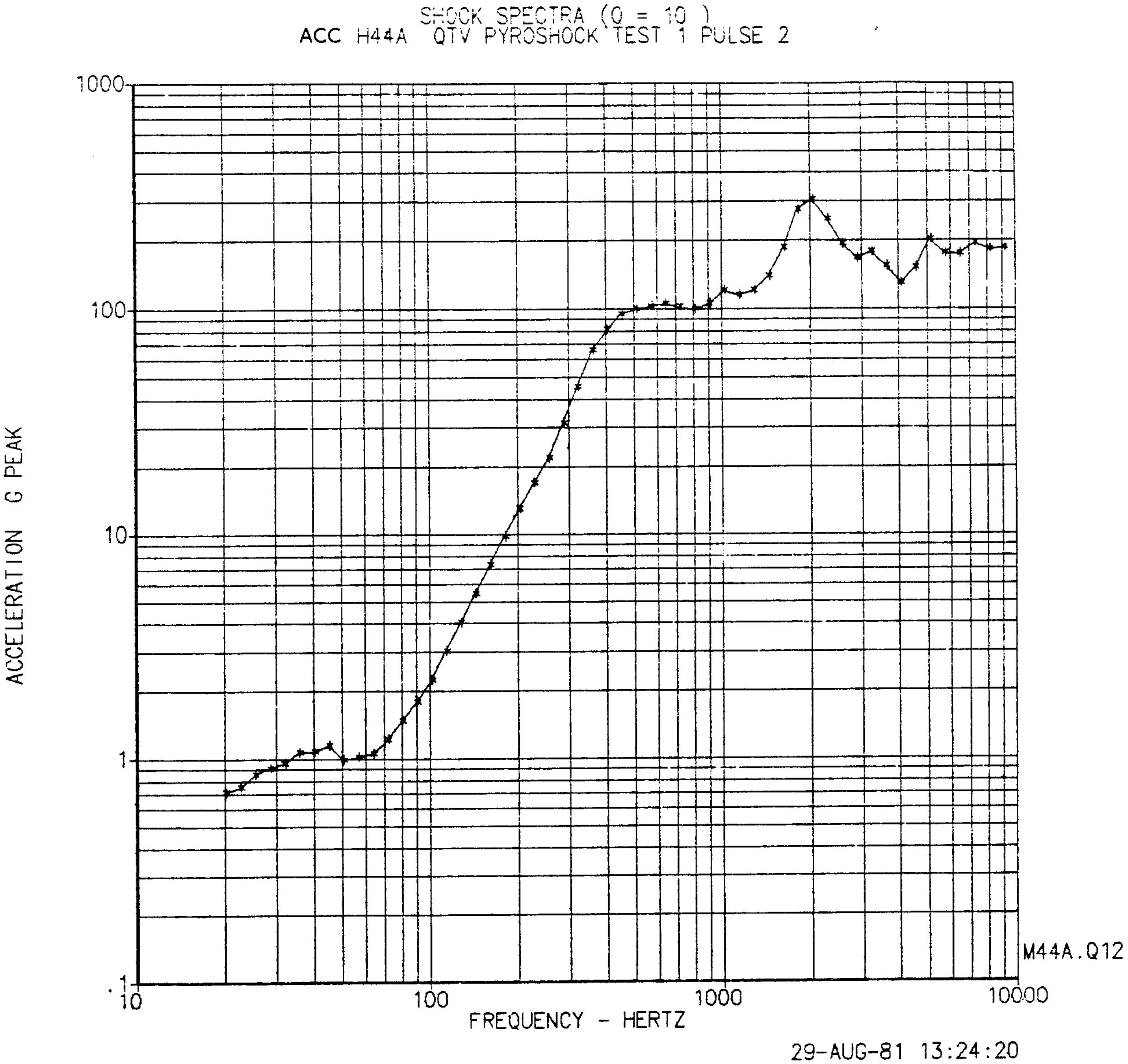

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Figure 3.3.2.1-3

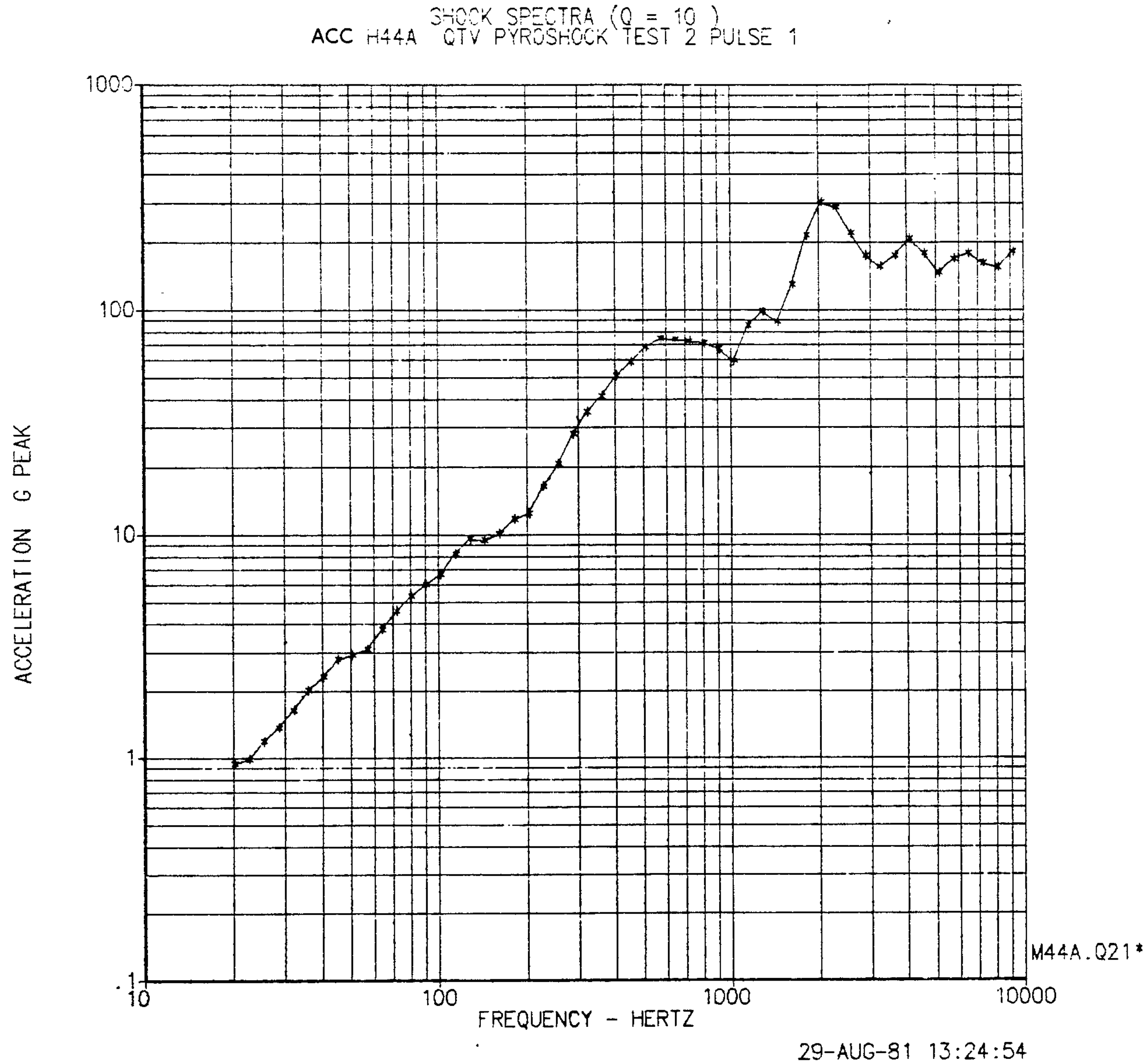

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Figure 3.3.2.1-4

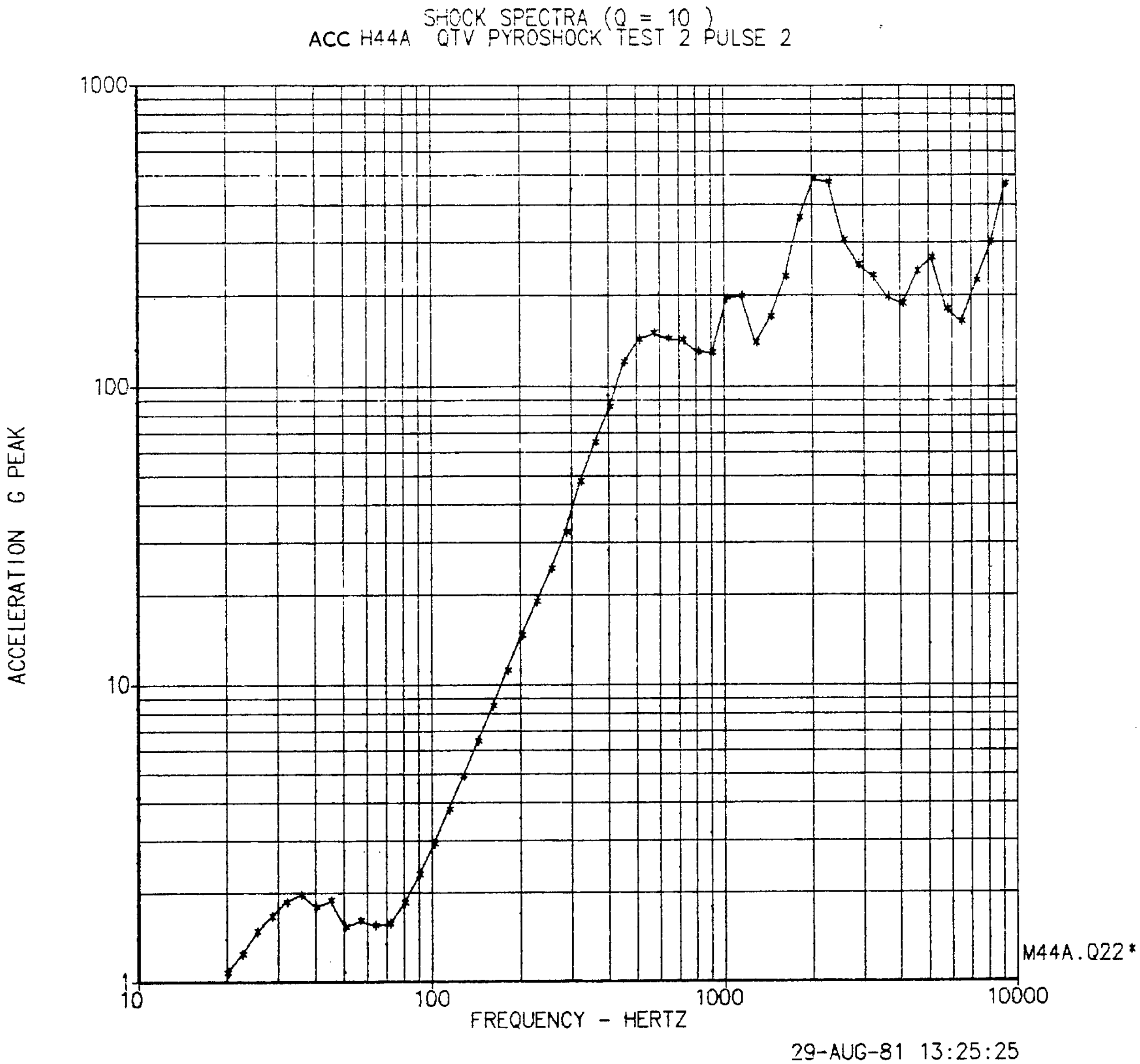

Figure 3.3.2.1-5

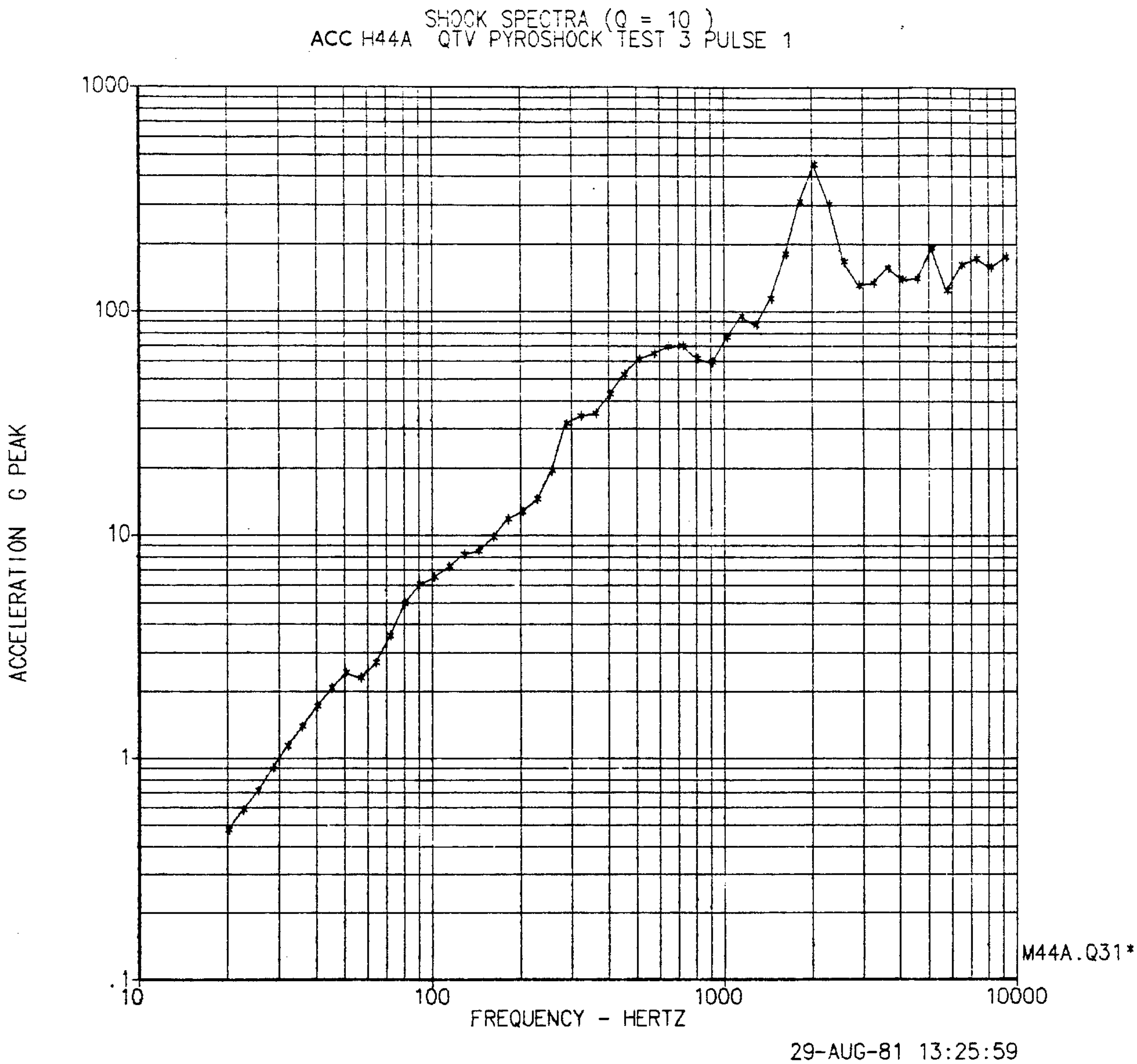

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Figure 3.3.2.1-6

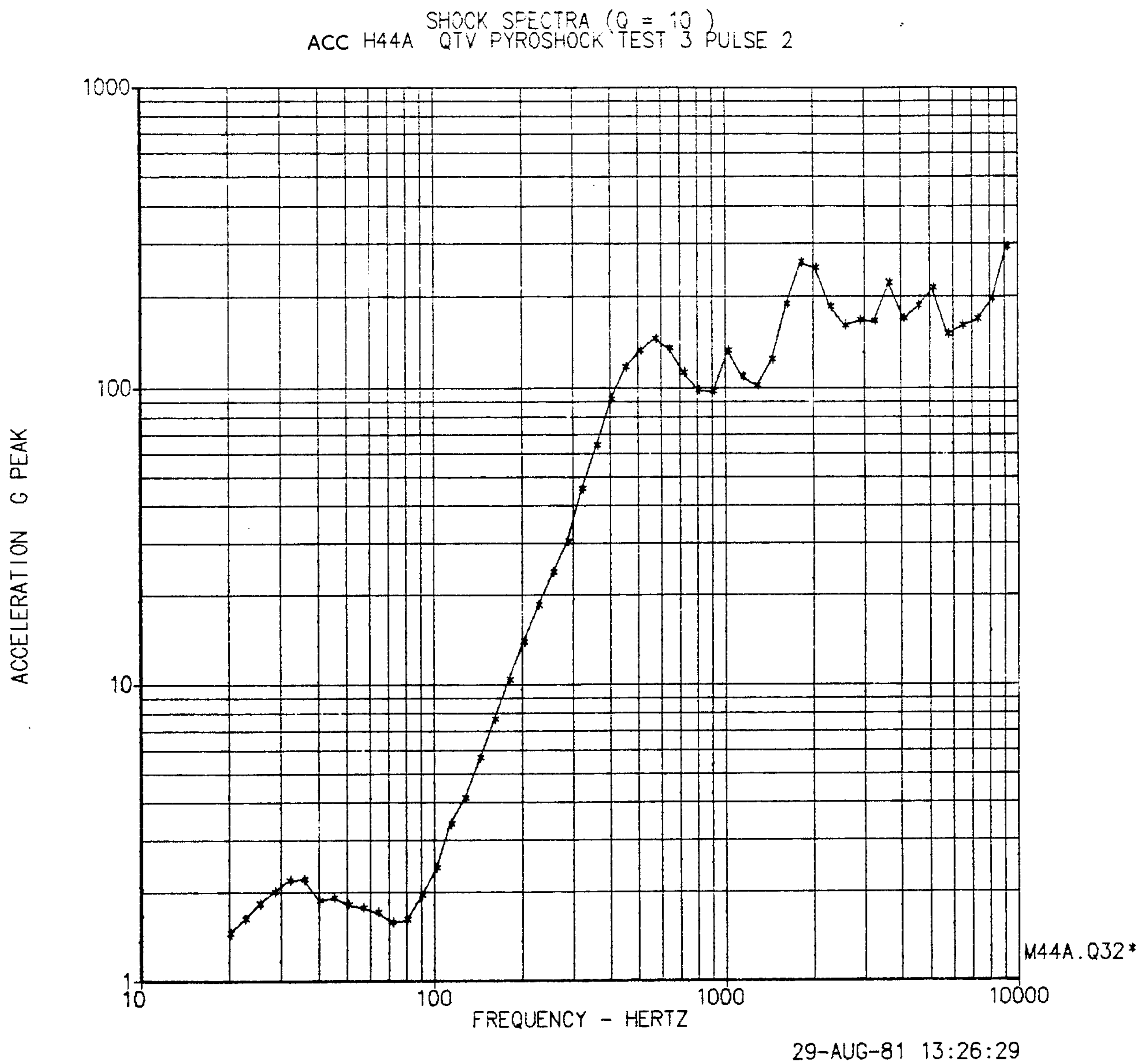

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Figure 3.3.2.1-7

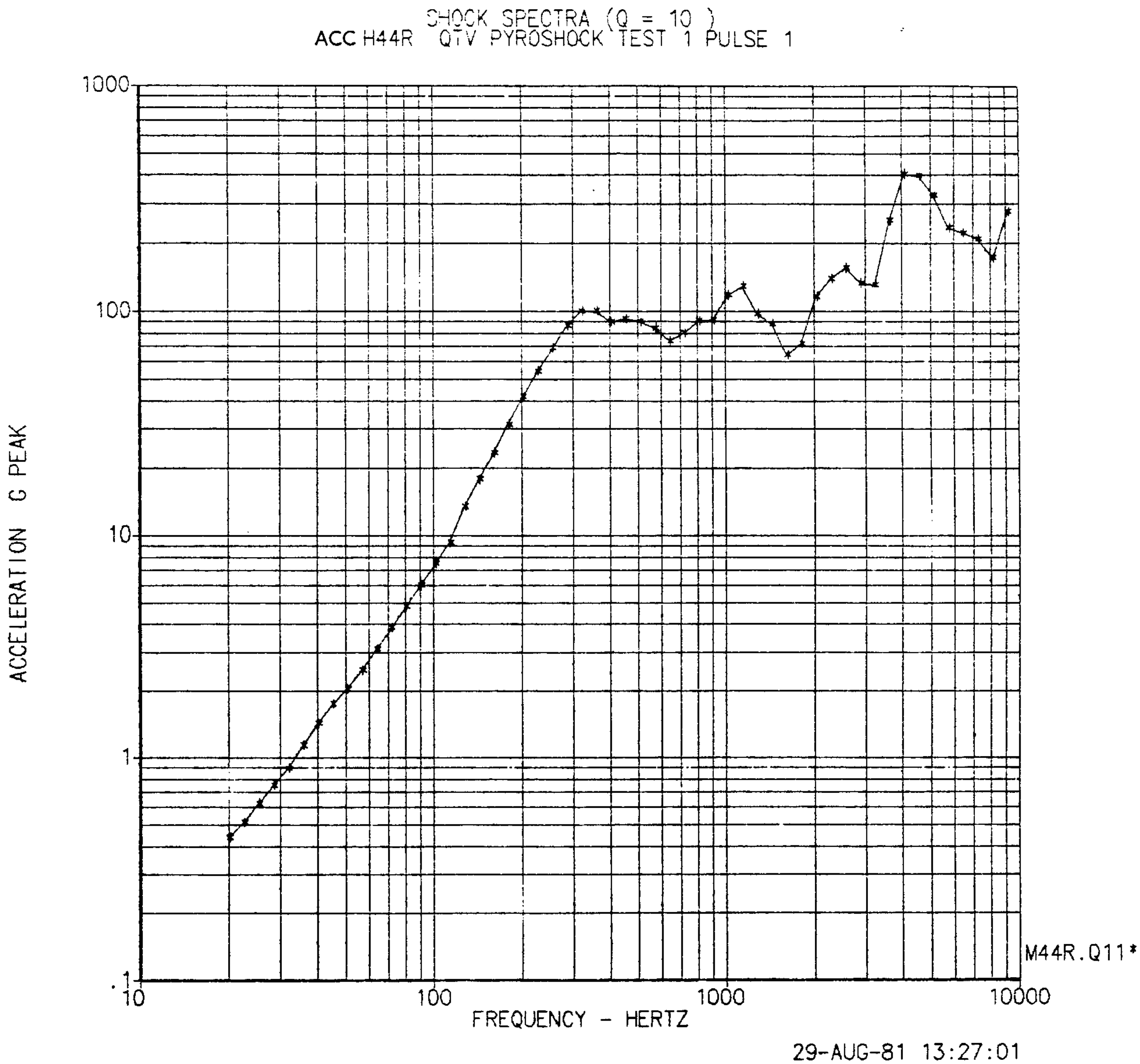

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Figure 3.3.2.1-8

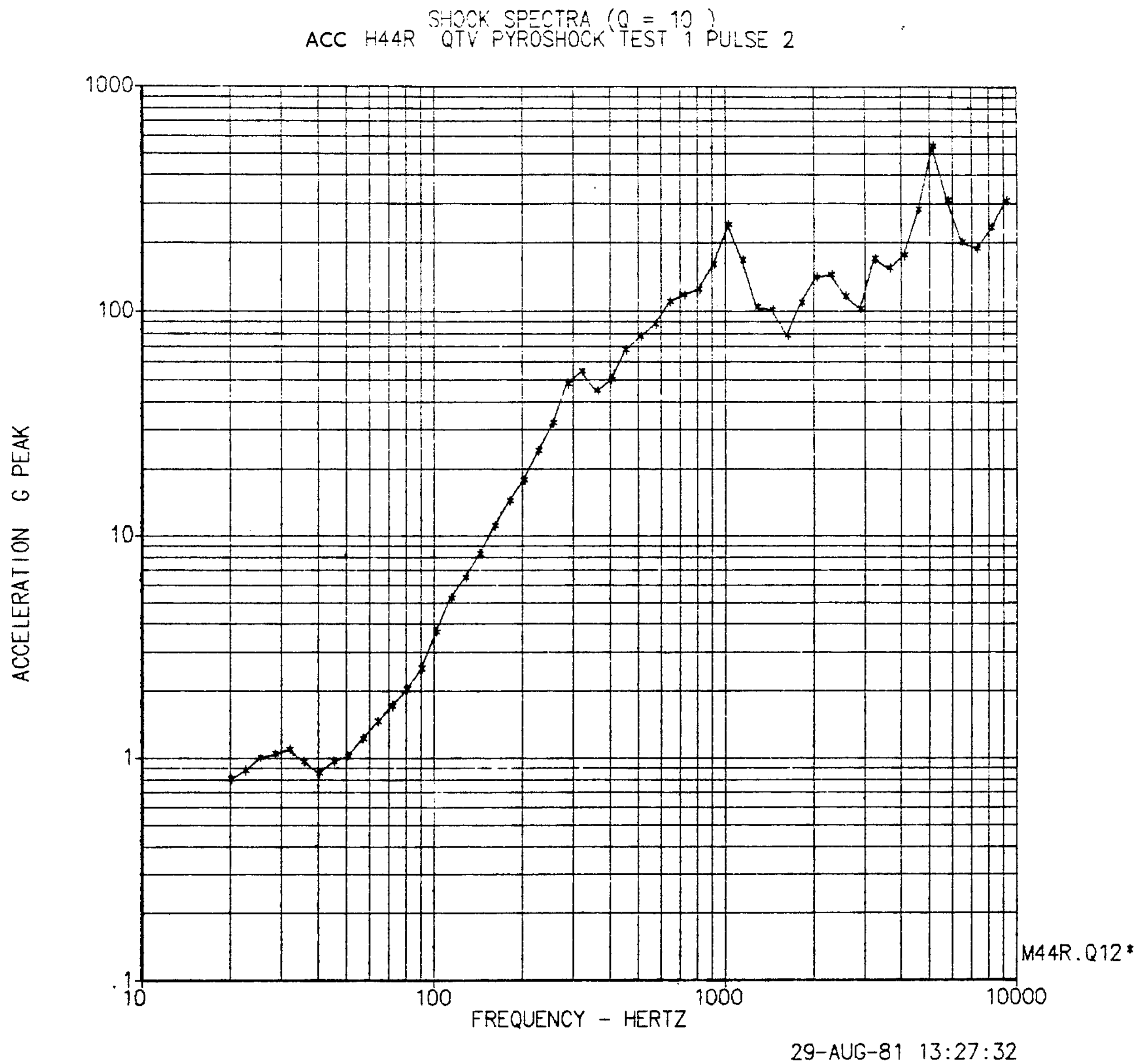

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Figure 3.3.2.1-9

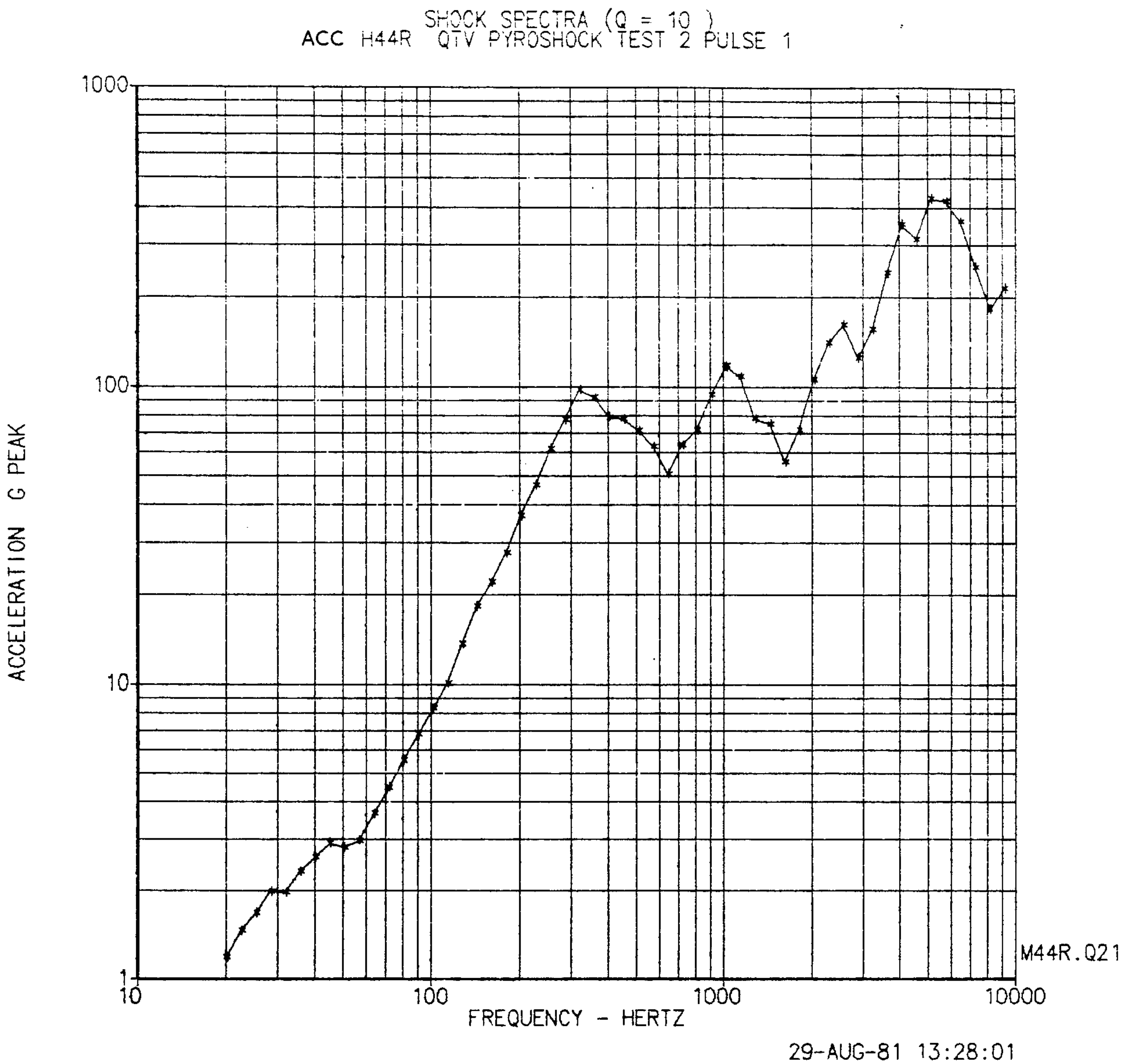

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Figure 3.3.2.1-10

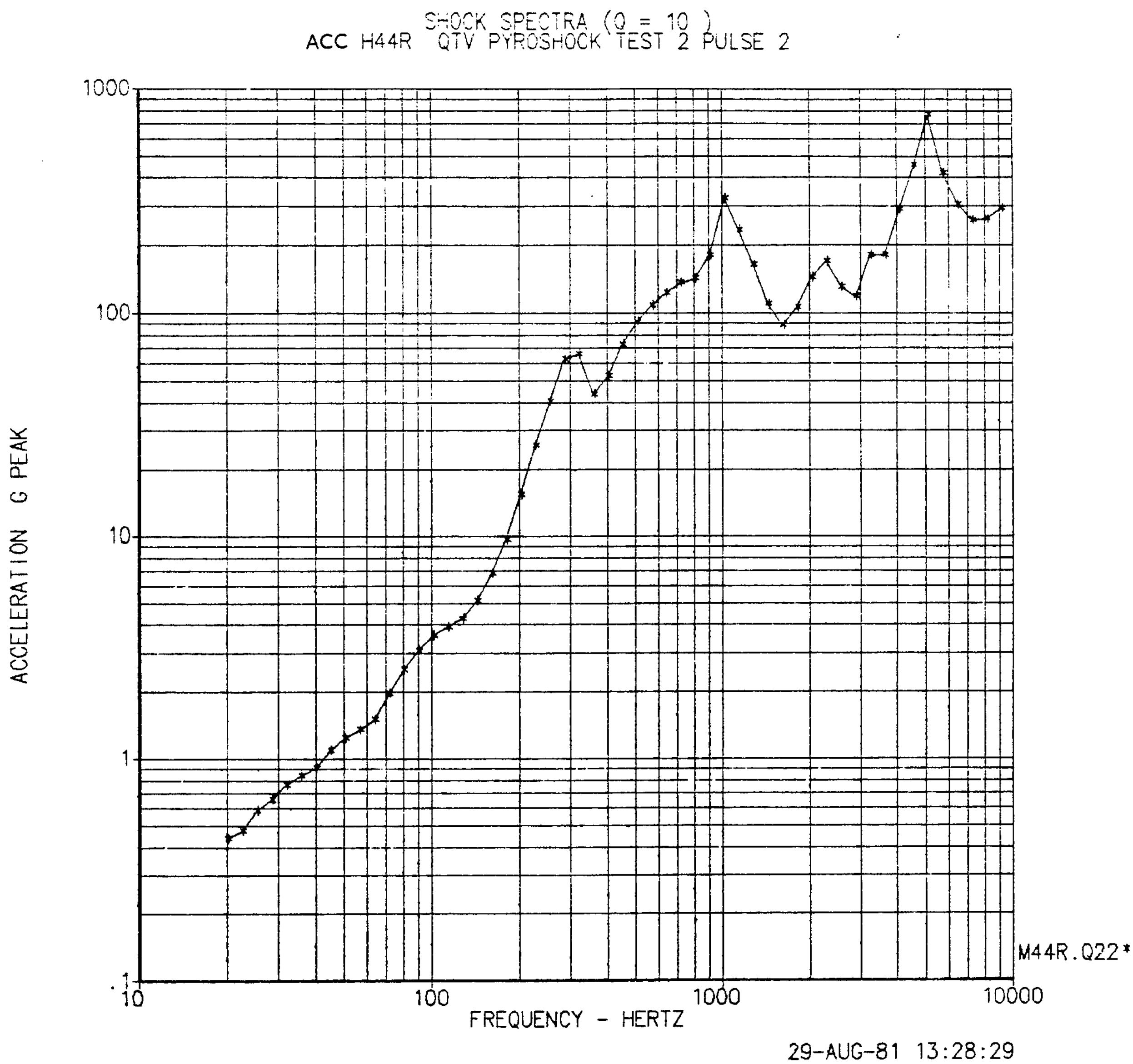

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Figure 3.3.2.1-11

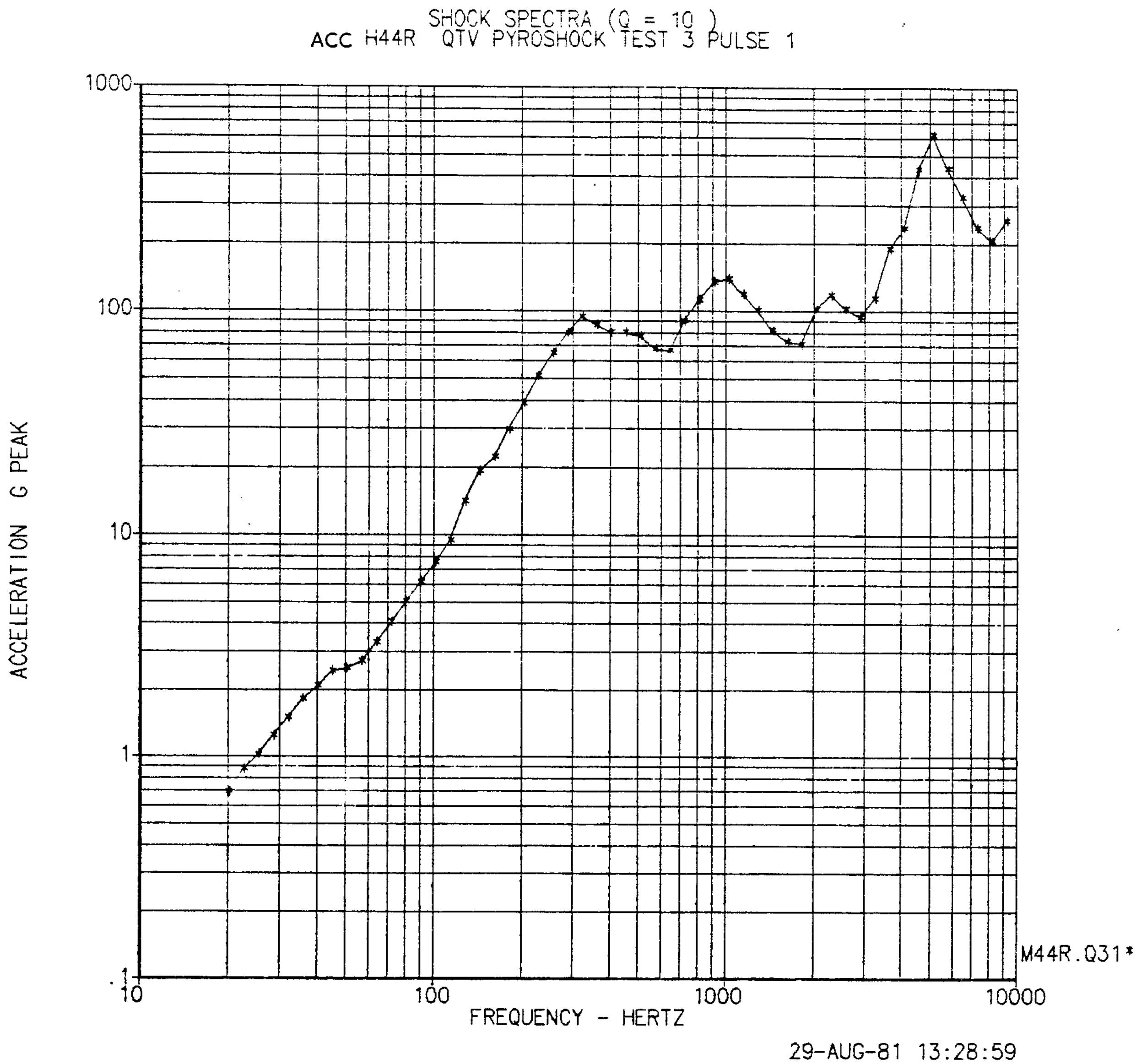

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Figure 3.3.2.1-12

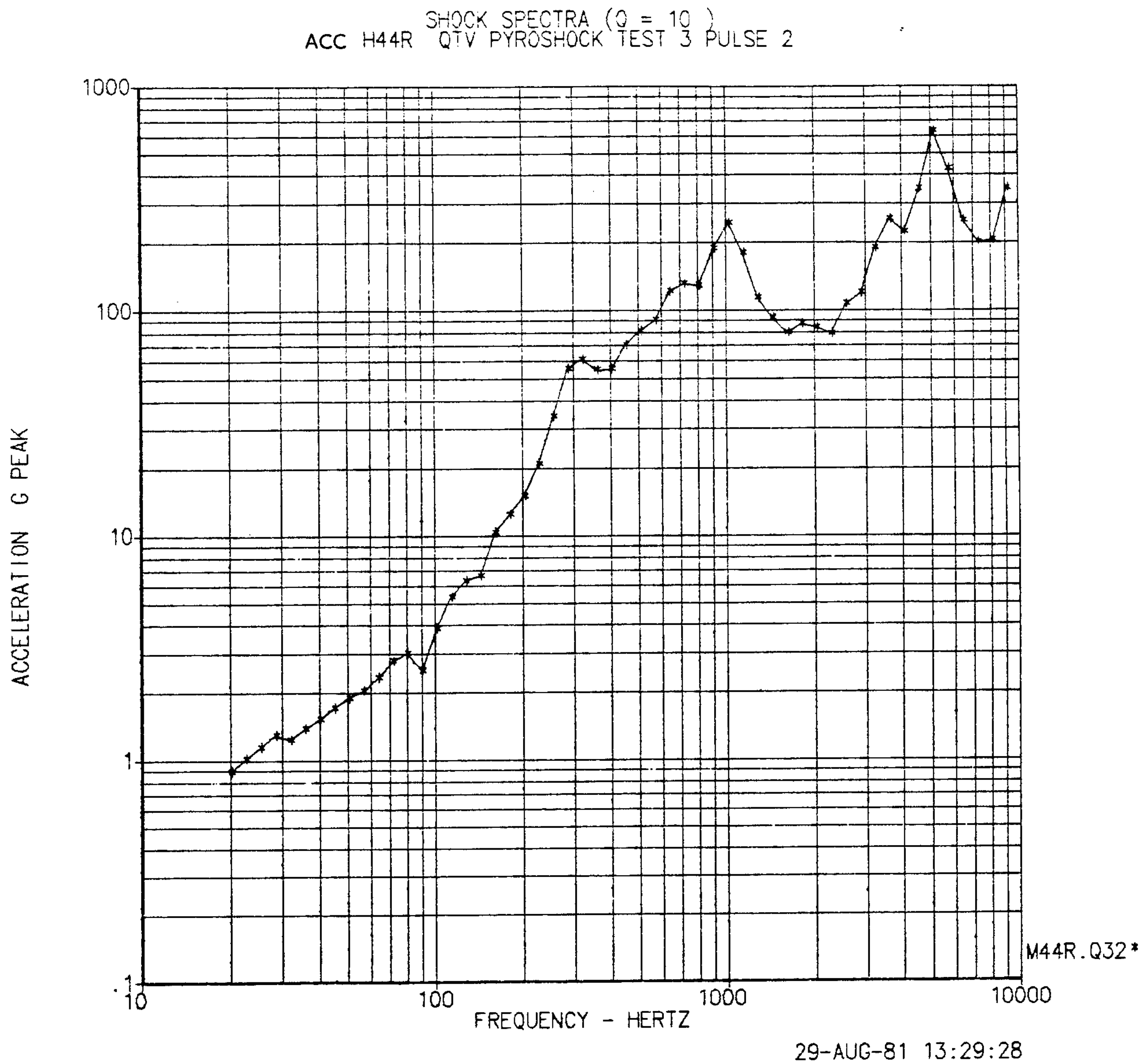

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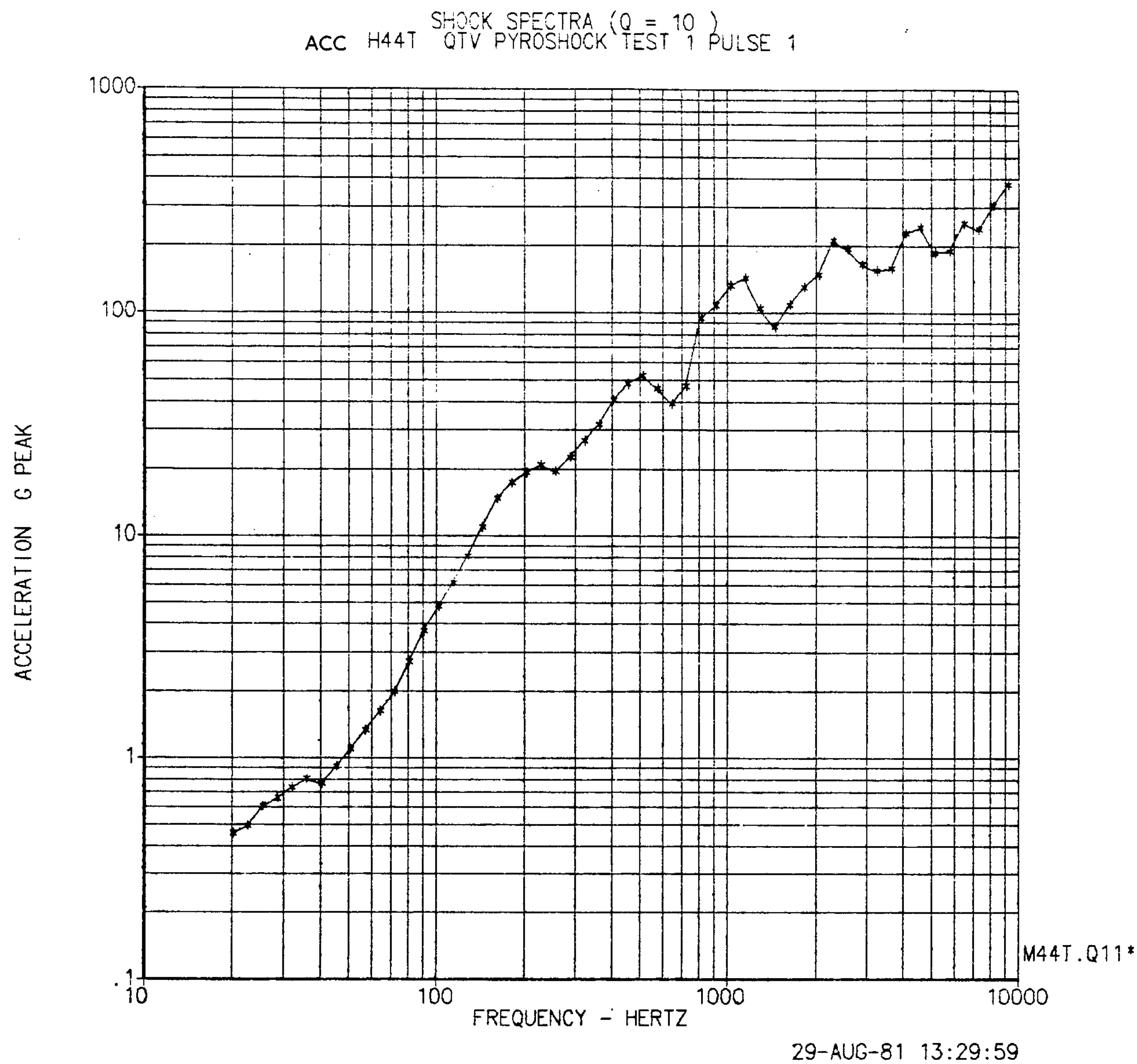
Figure 3.3.2.1-13



CALC		29AUG81	REVISED	DATE	RF Switch I/II Staging Pyroshock Environment
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Figure 3.3.2.1-14

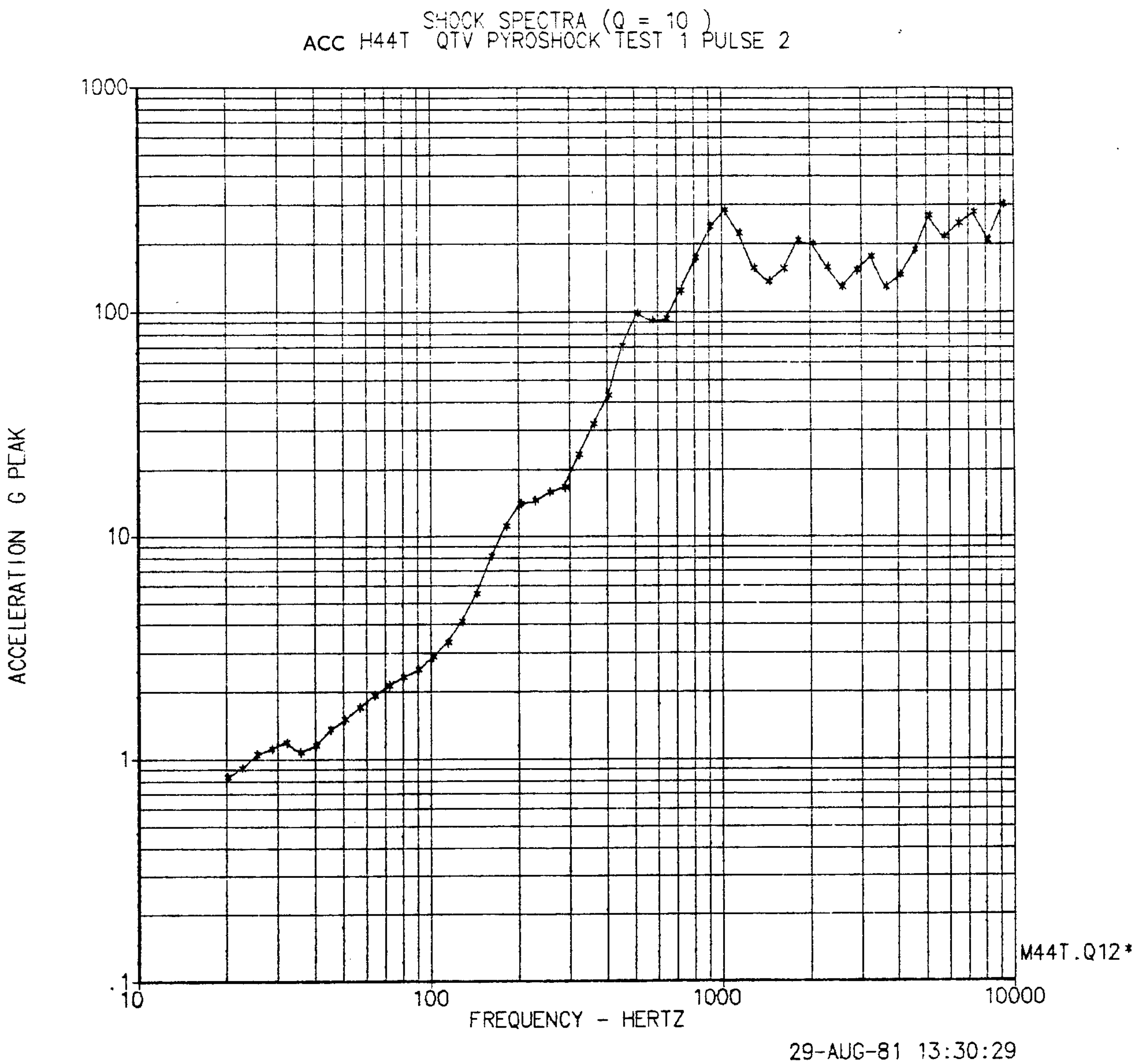

Figure 3.3.2.1-15

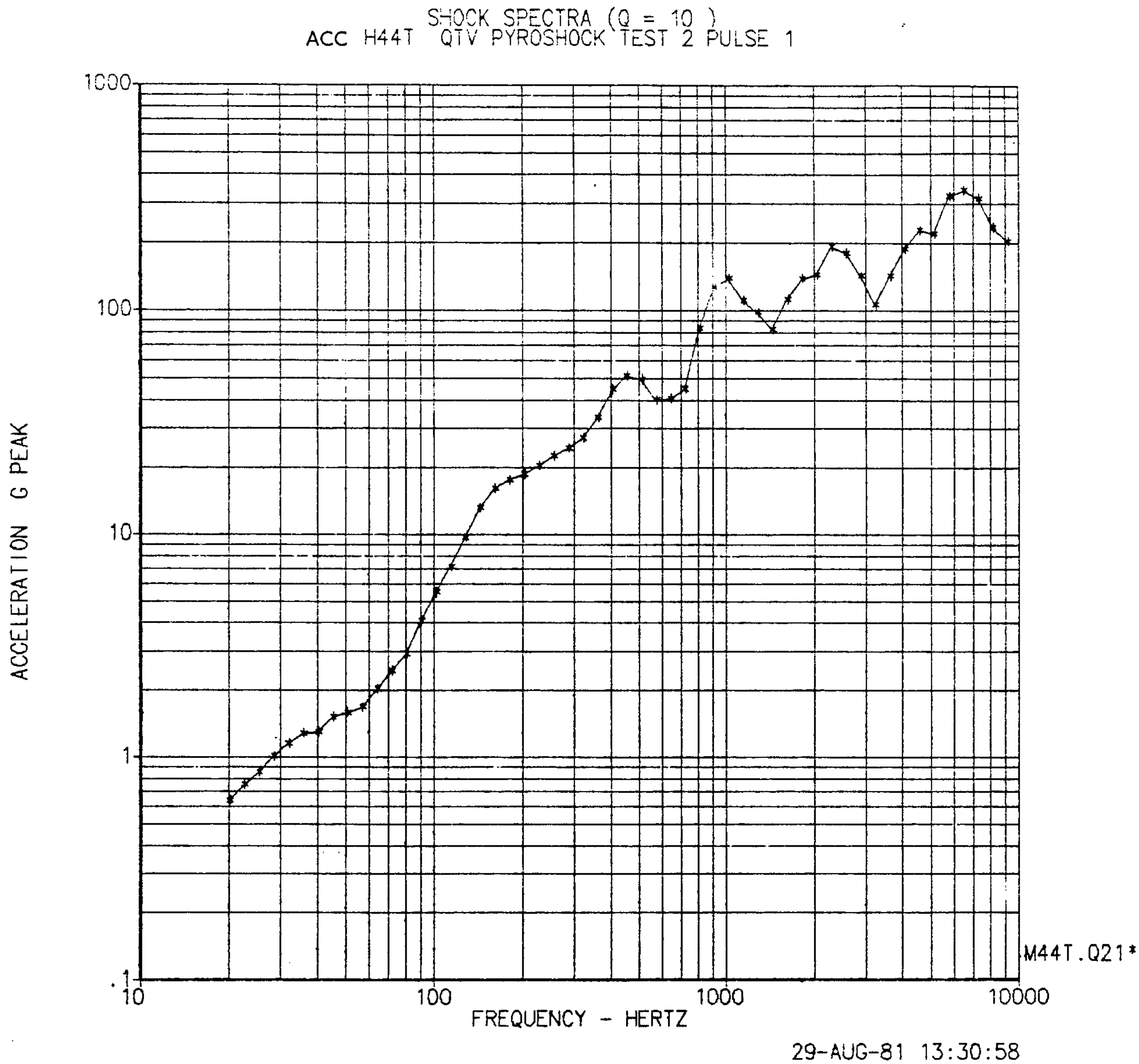

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Figure 3.3.2.1-16

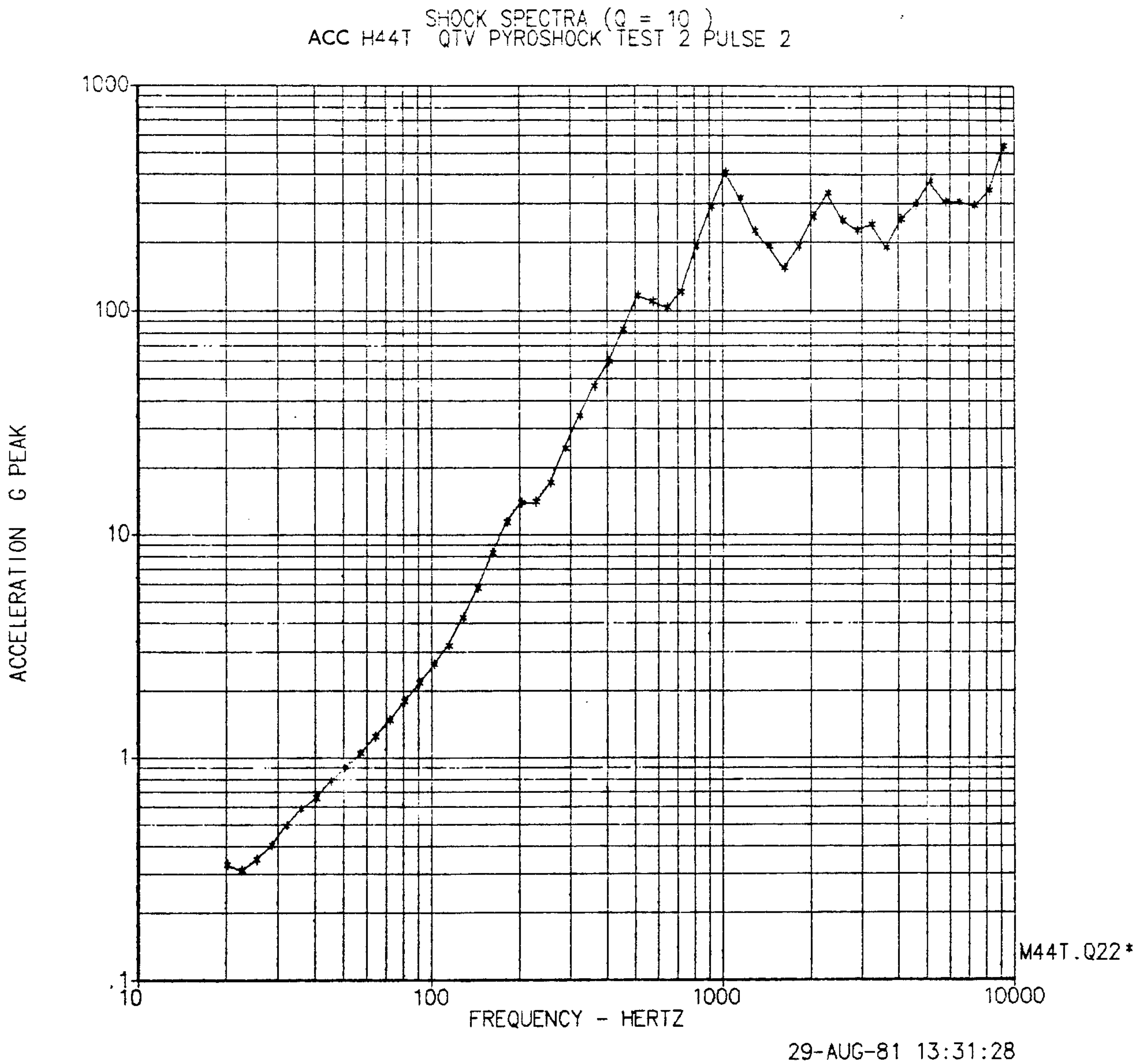

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Figure 3.3.2.1-17

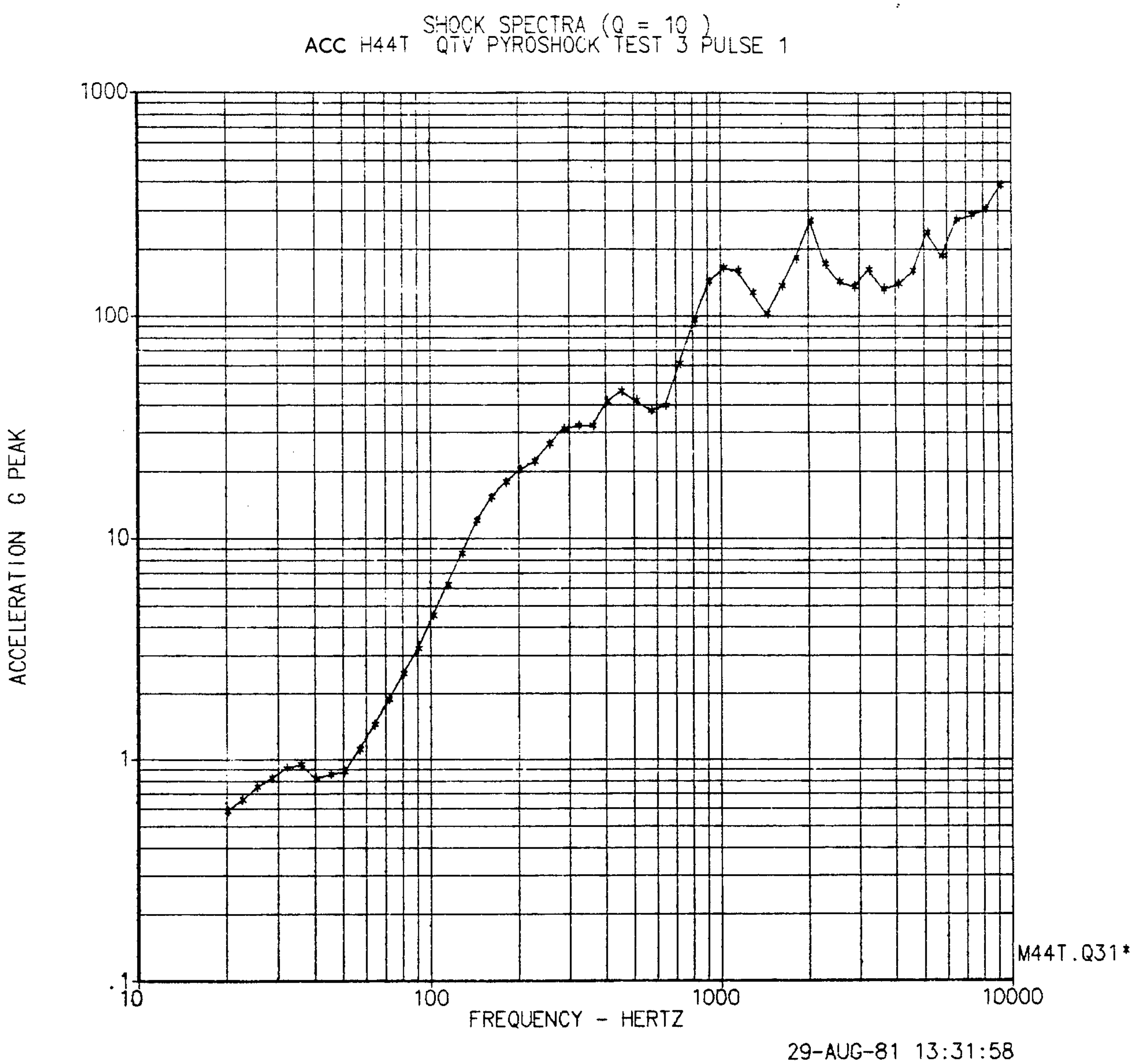

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Figure 3.3.2.1-18

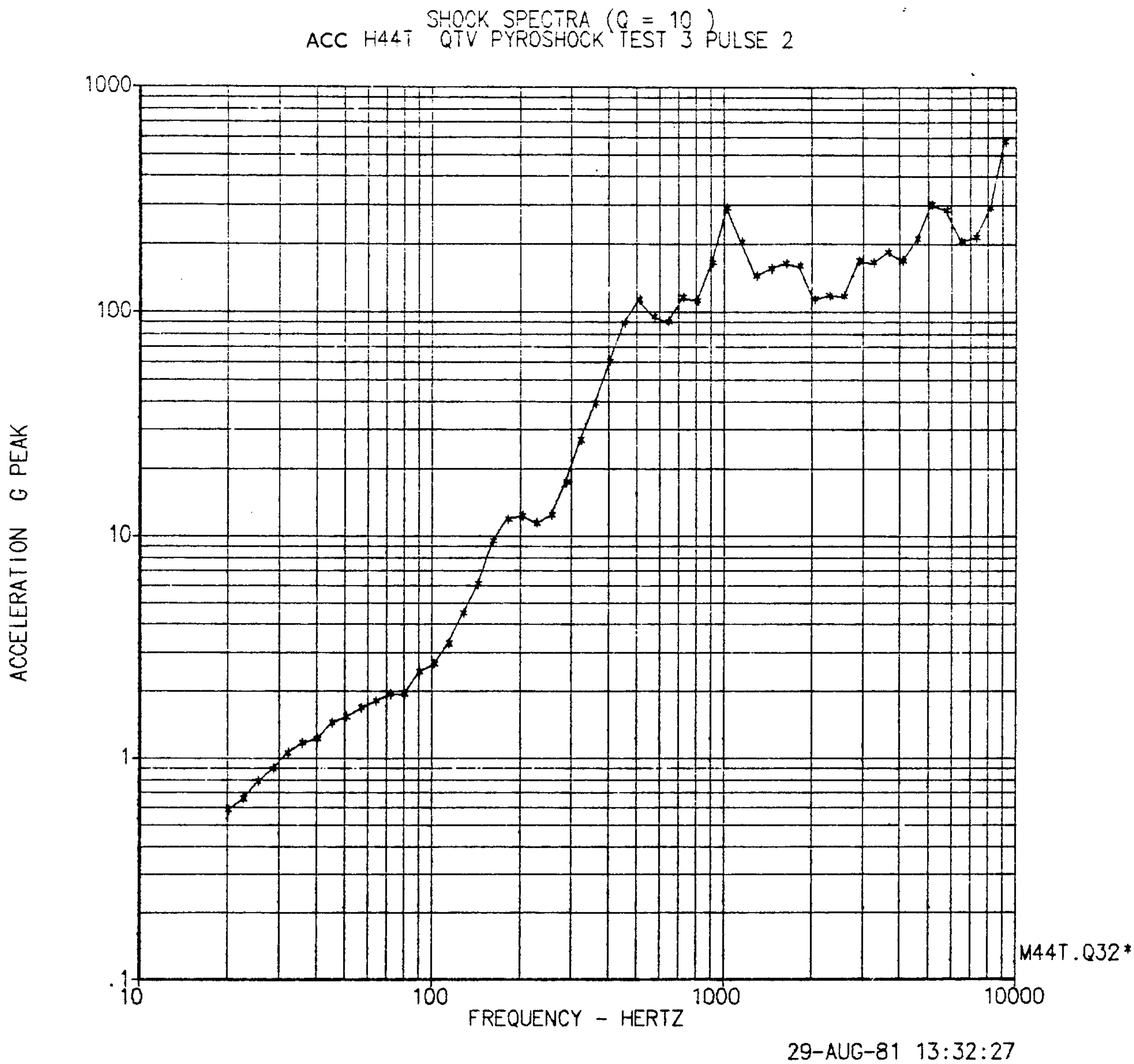

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Figure 3.3.2.1-19

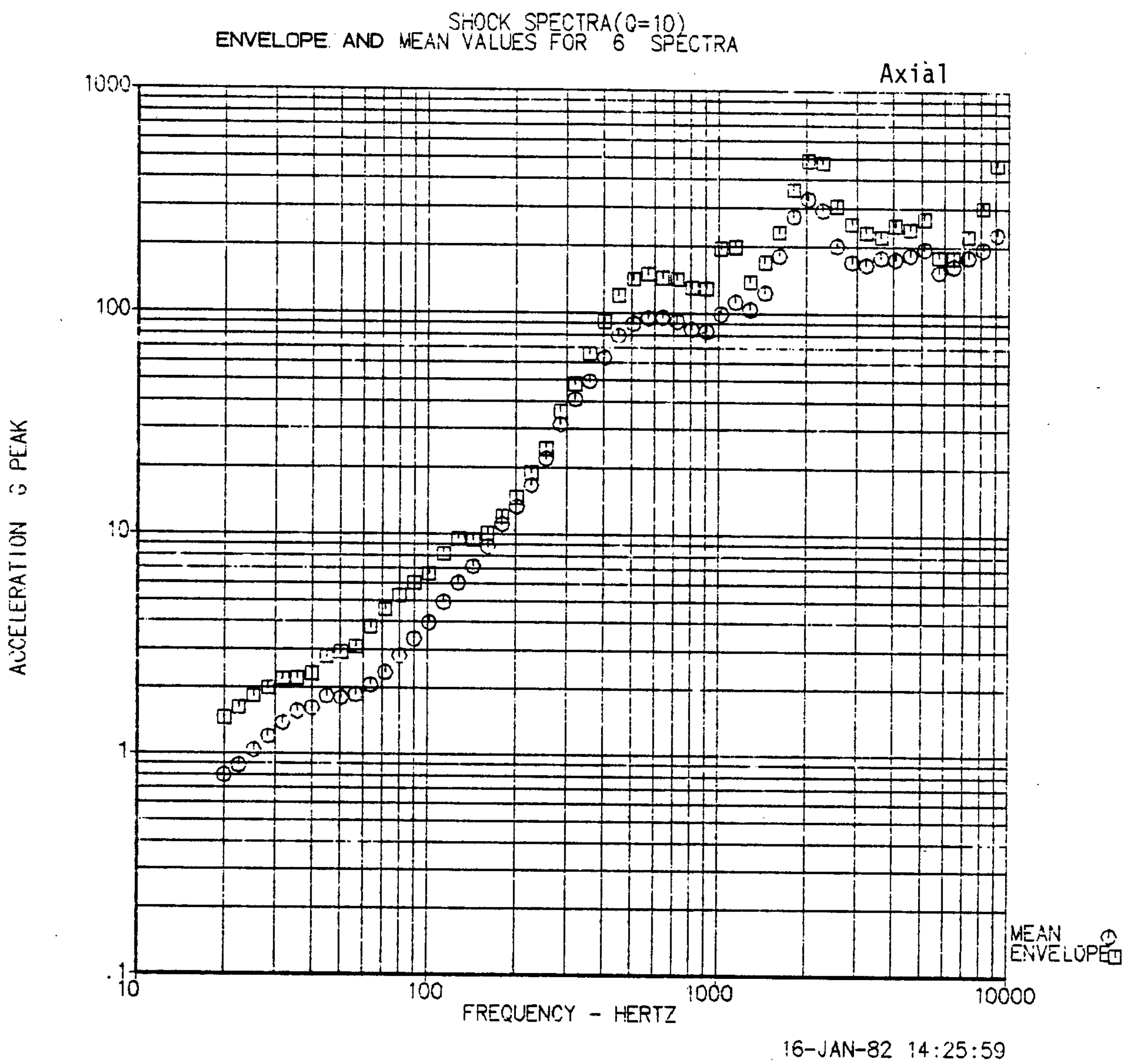

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Figure 3.3.2.1-20

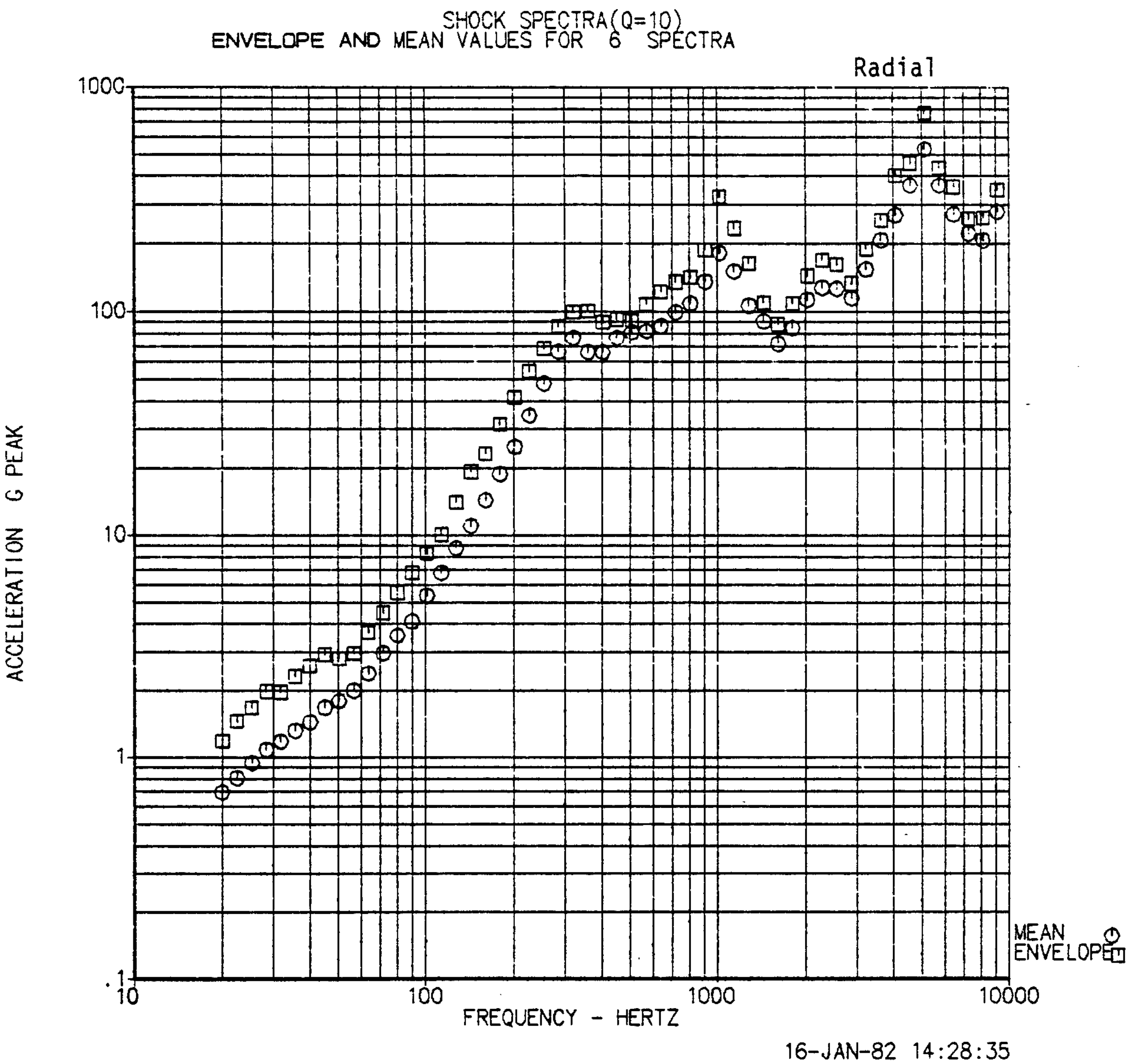

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Figure 3.3.2.1-21

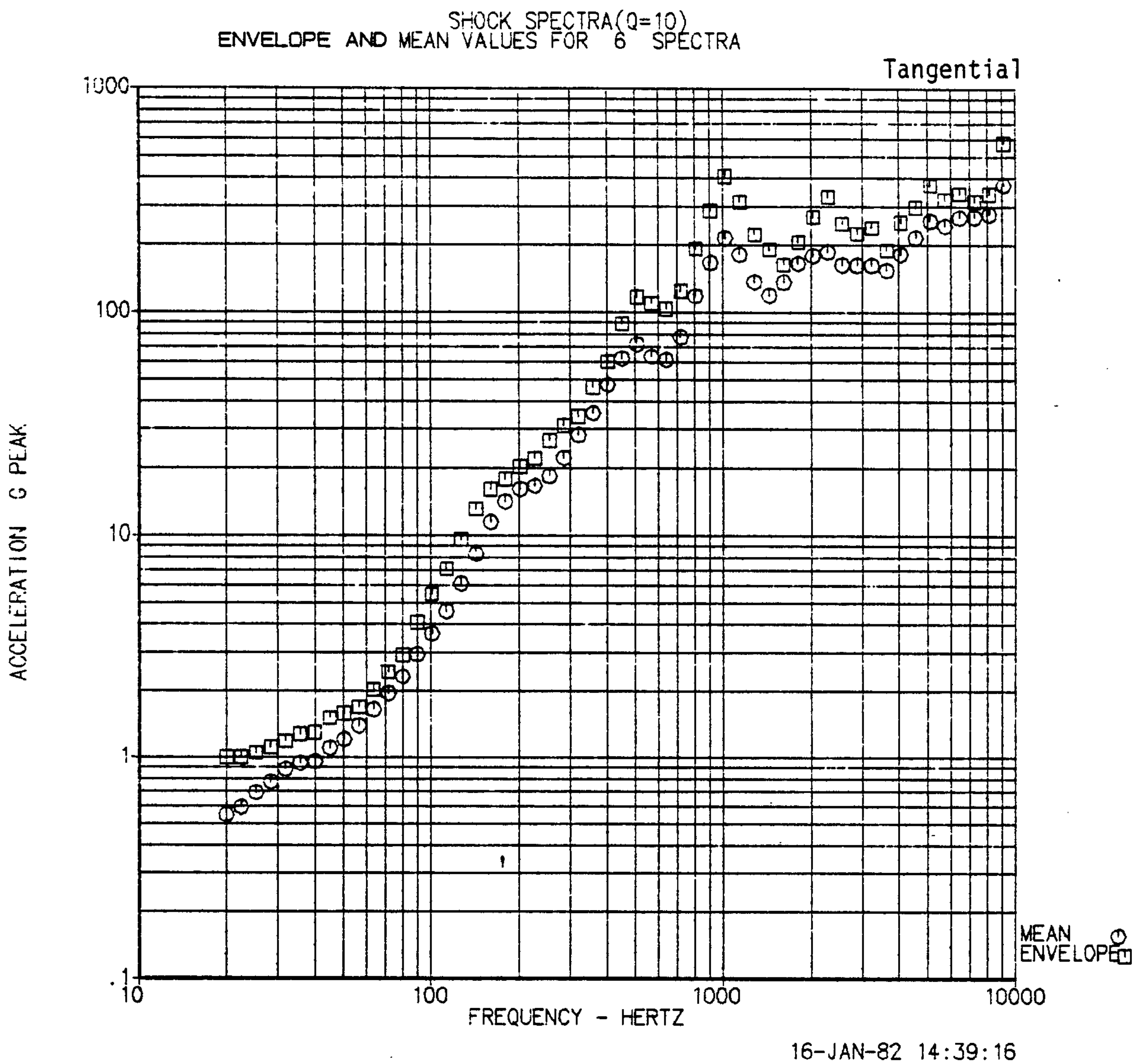

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Figure 3.3.2.1-22

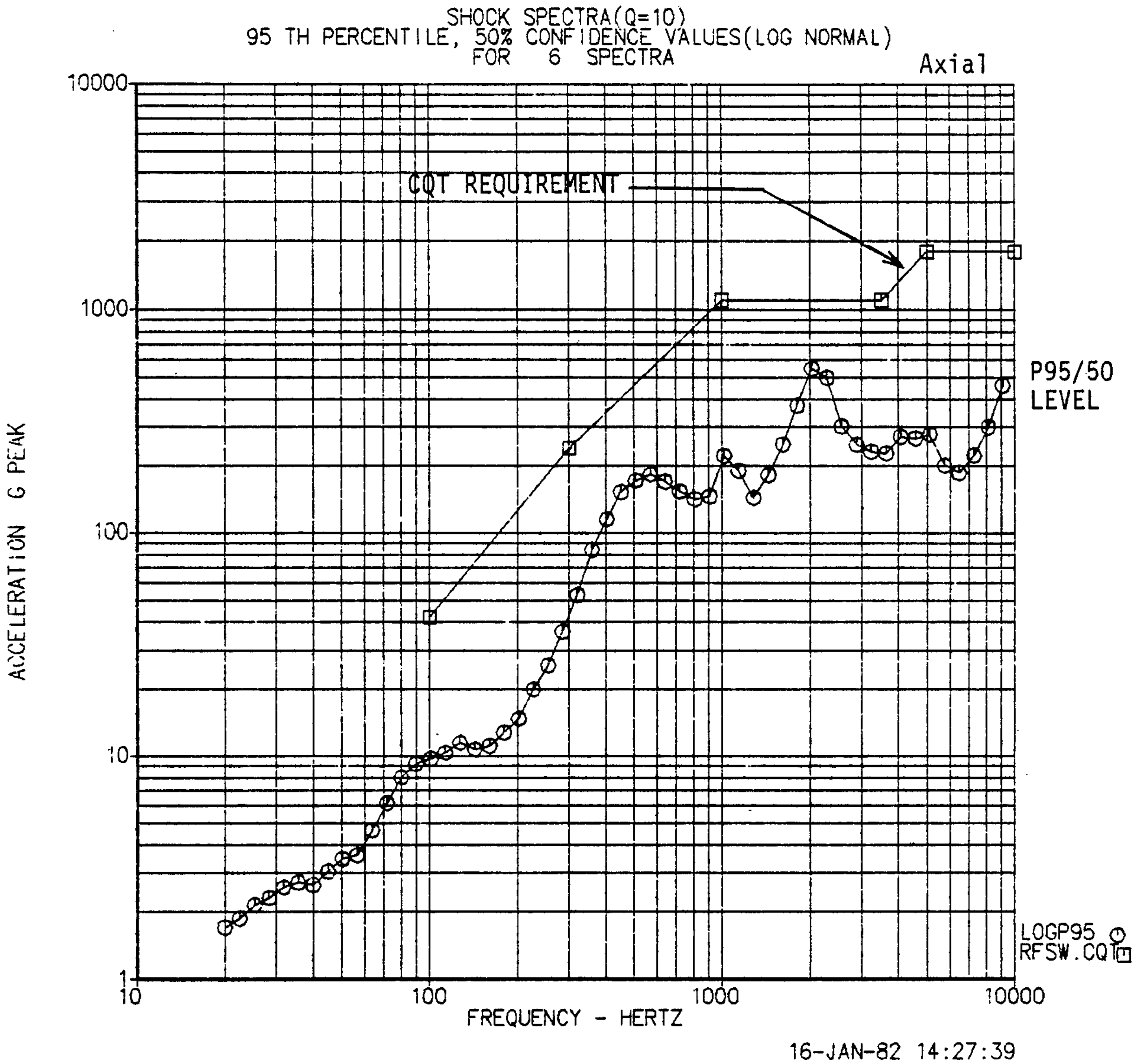

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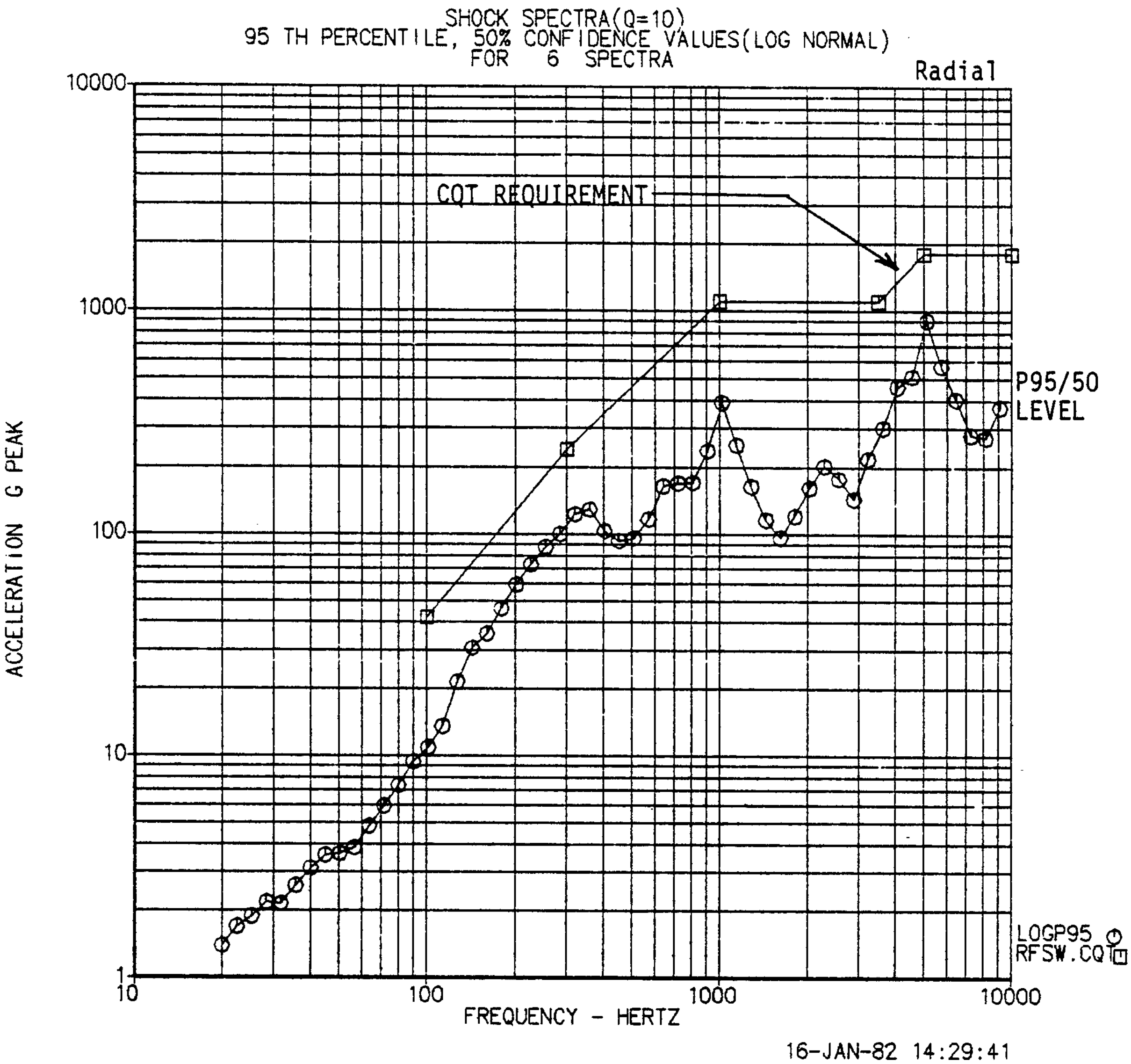
Figure 3.3.2.1-23



CALC	Fzaun	16JAN82	REVISED	DATE	Comparison of RF Switch Shock Environment with CQT Requirement	
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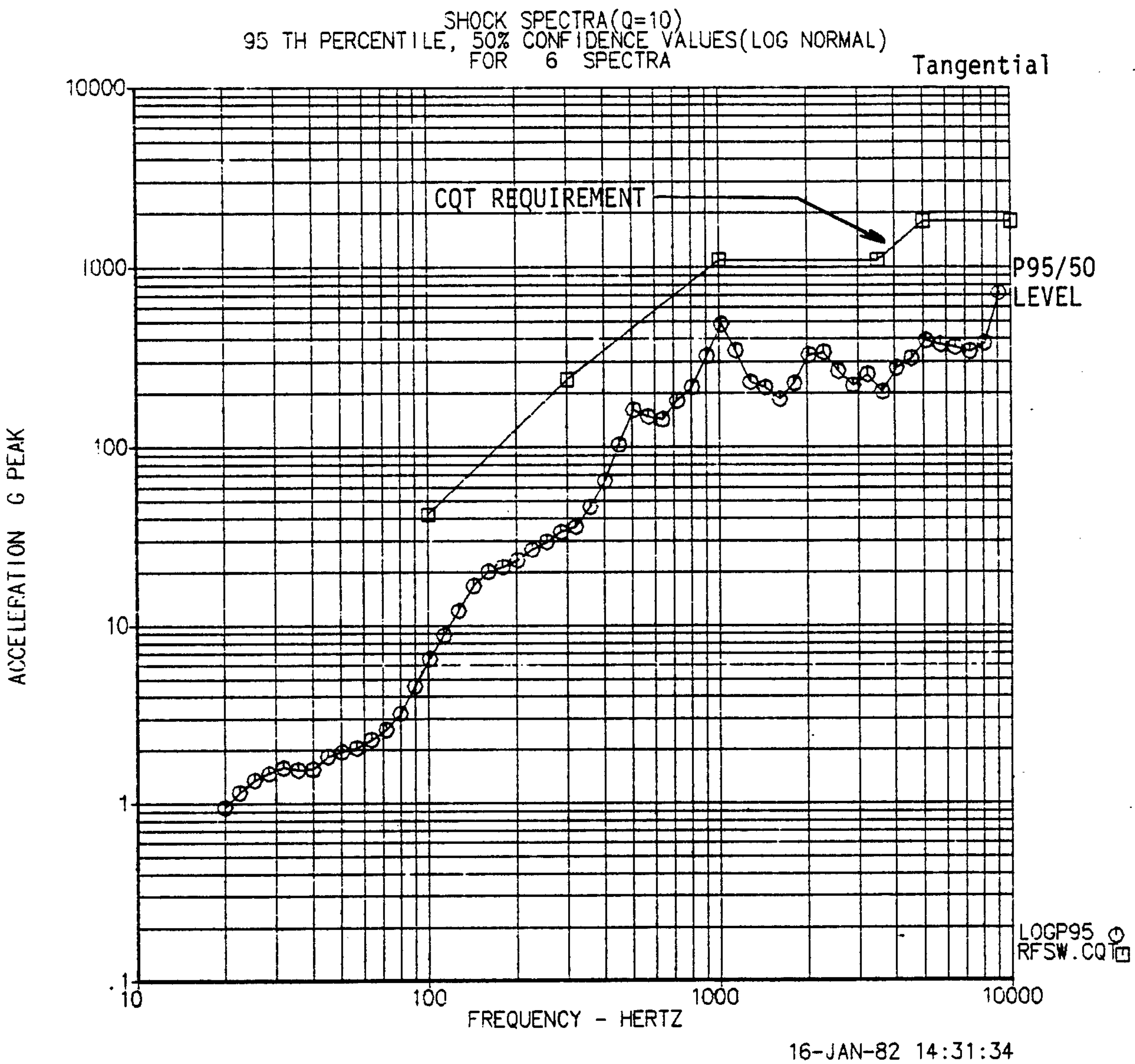
Figure 3.3.2.1-24



CALC		16JAN82	REVISED	DATE	Comparison of RF Switch Shock Environment with CQT Requirement	
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Figure 3.3.2.2-1

ENVELOPE OF ACC. 47A LOCATED AT POSITION OF TIU ON ESS DECK

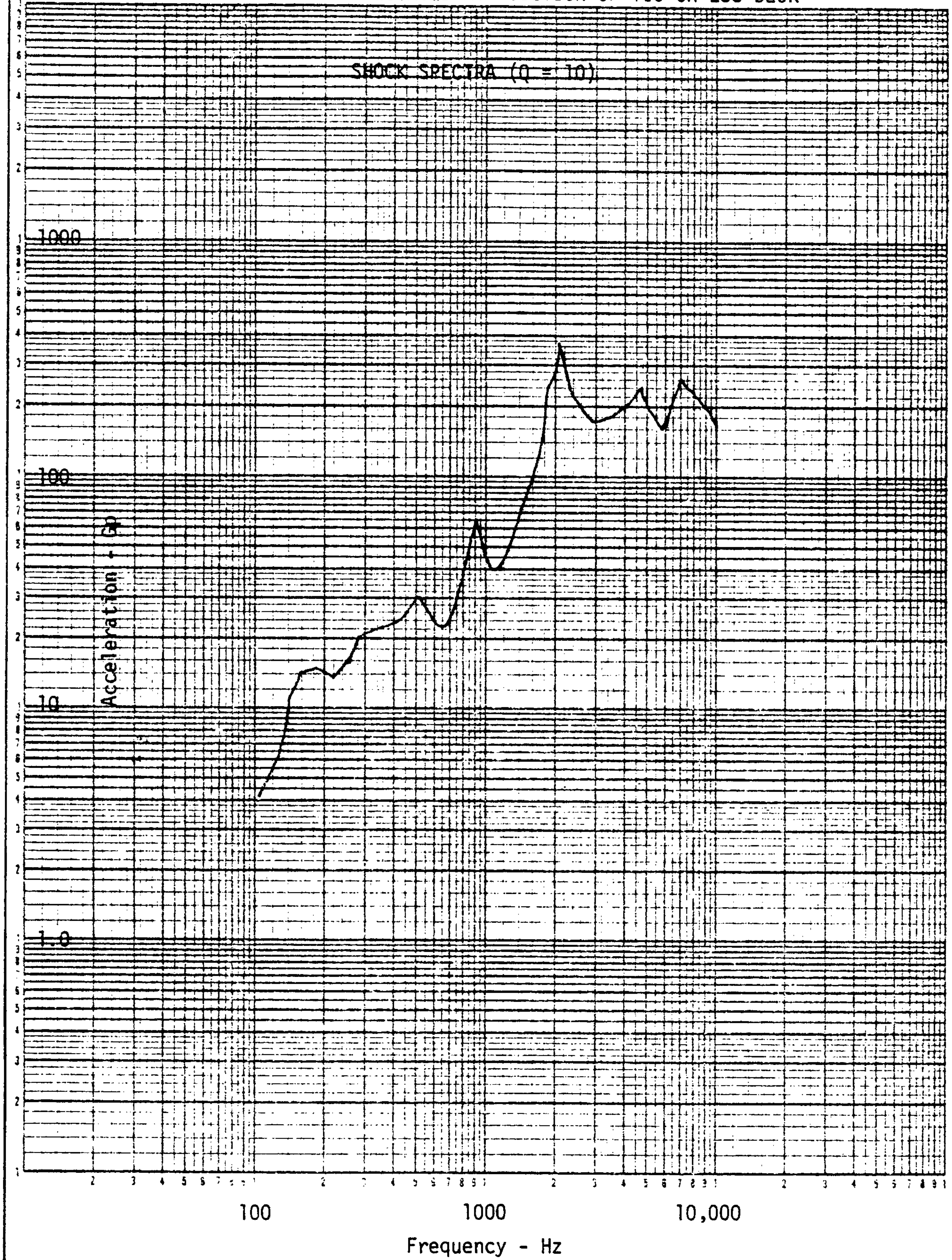

Figure 3.3.2.2-2

TIU ESS Deck Vibration Isolator

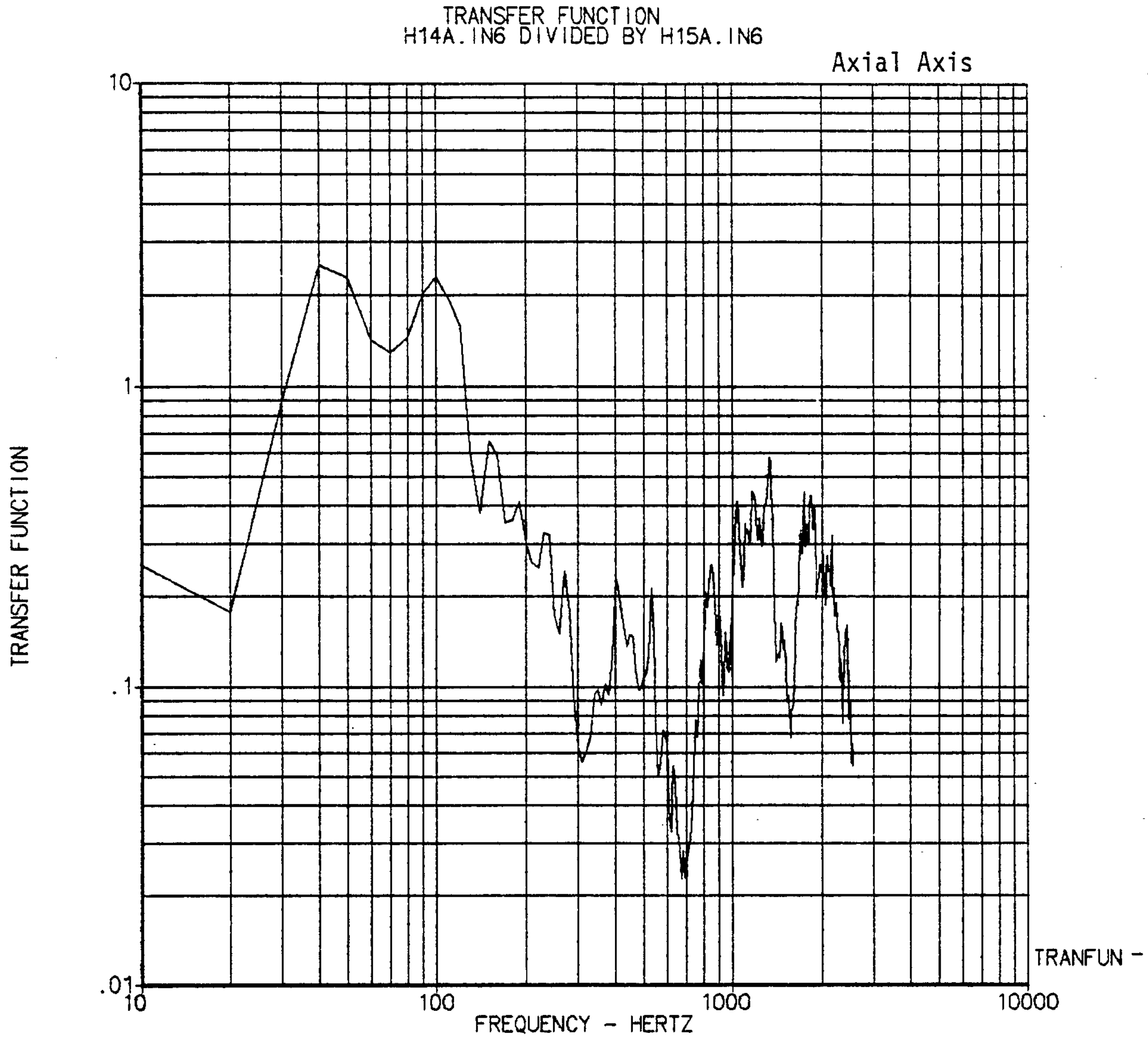

Figure 3.3.2.2-3

TIU ESS Deck Vibration Isolator

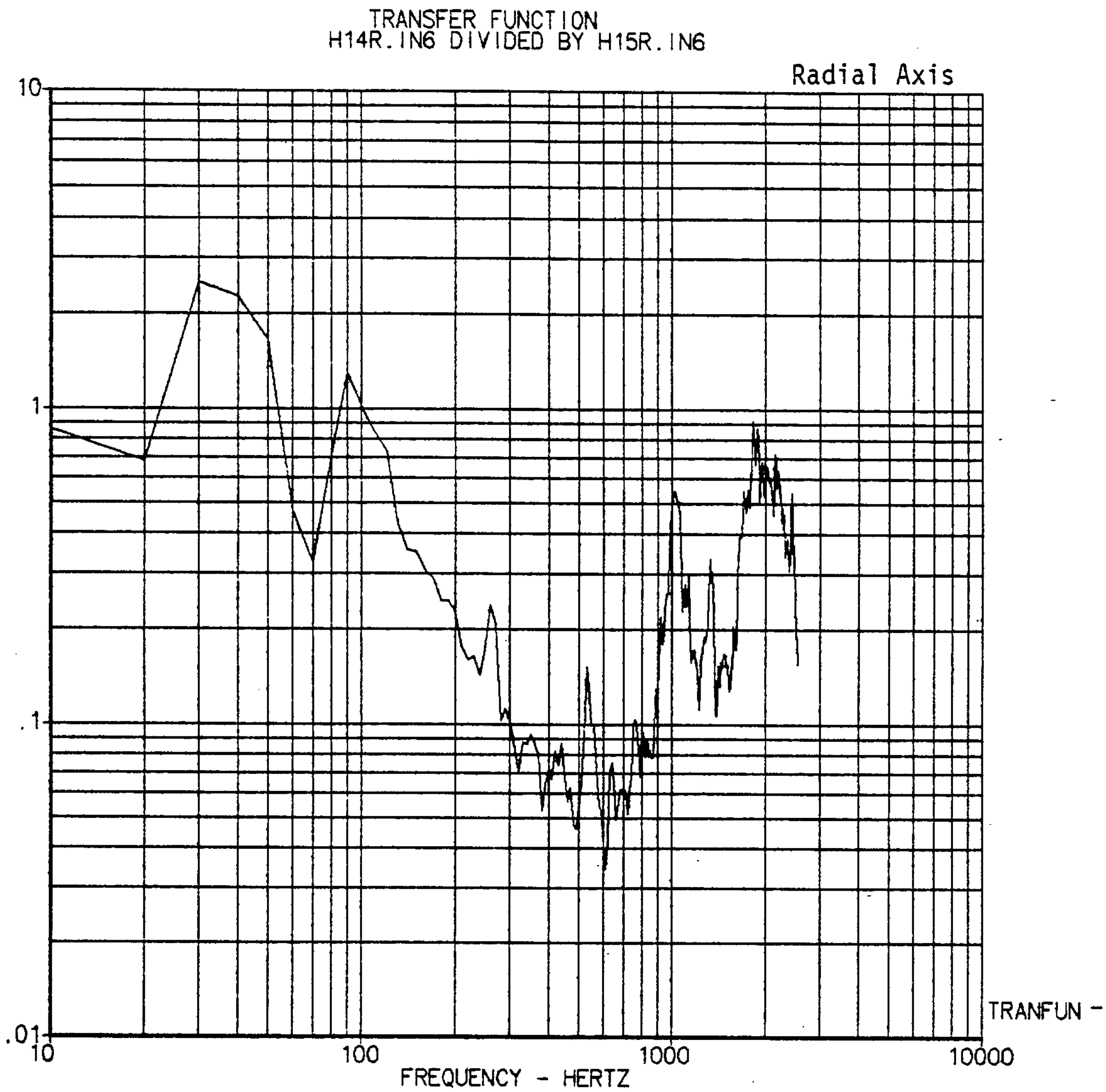

Figure 3.3.2.2-4

TIU ESS Deck Vibration Isolator

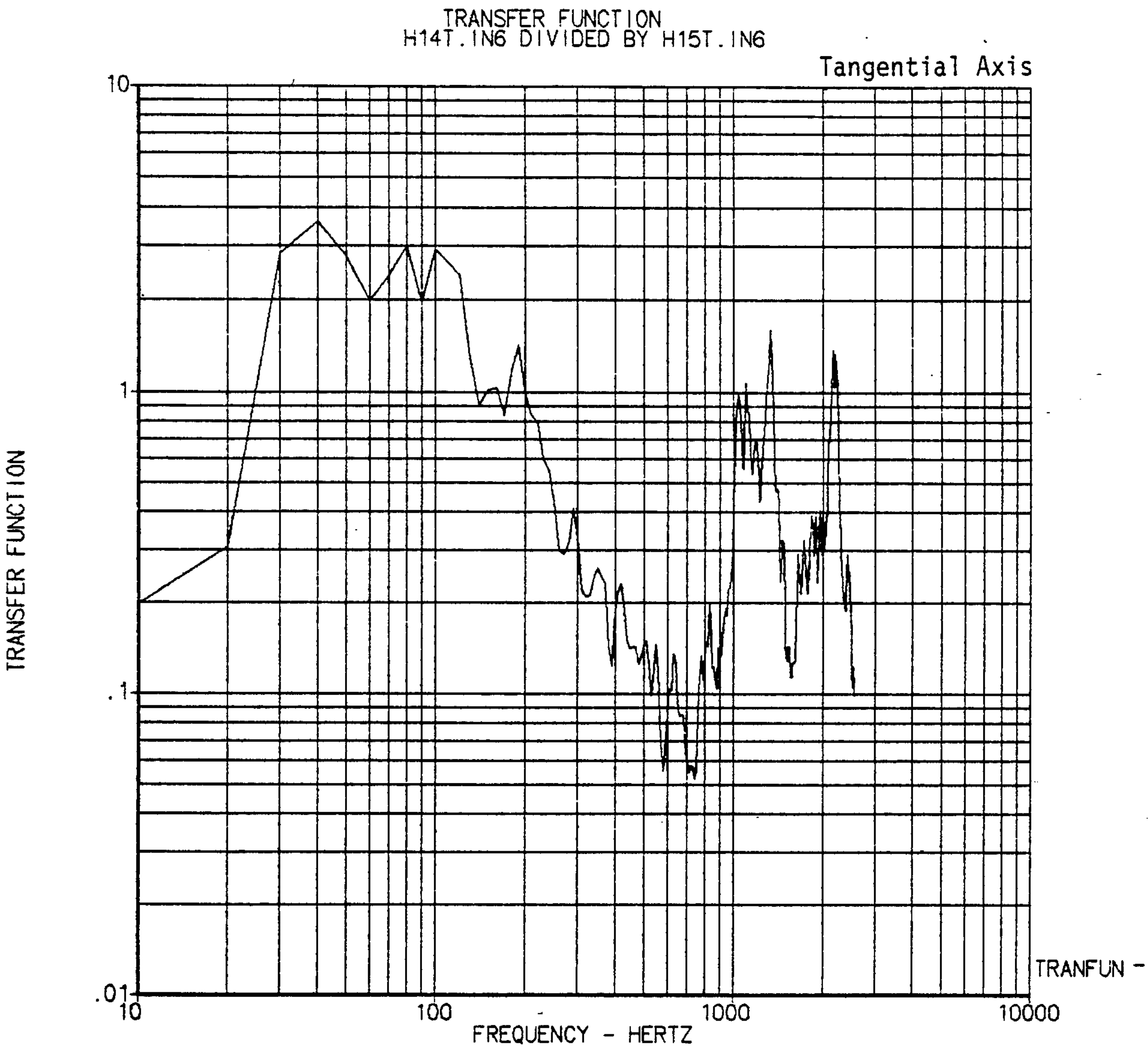

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Figure 3.3.2.2-5

COMPARISON OF PDU AND TIU INPUT SHOCK ENVIRONMENT

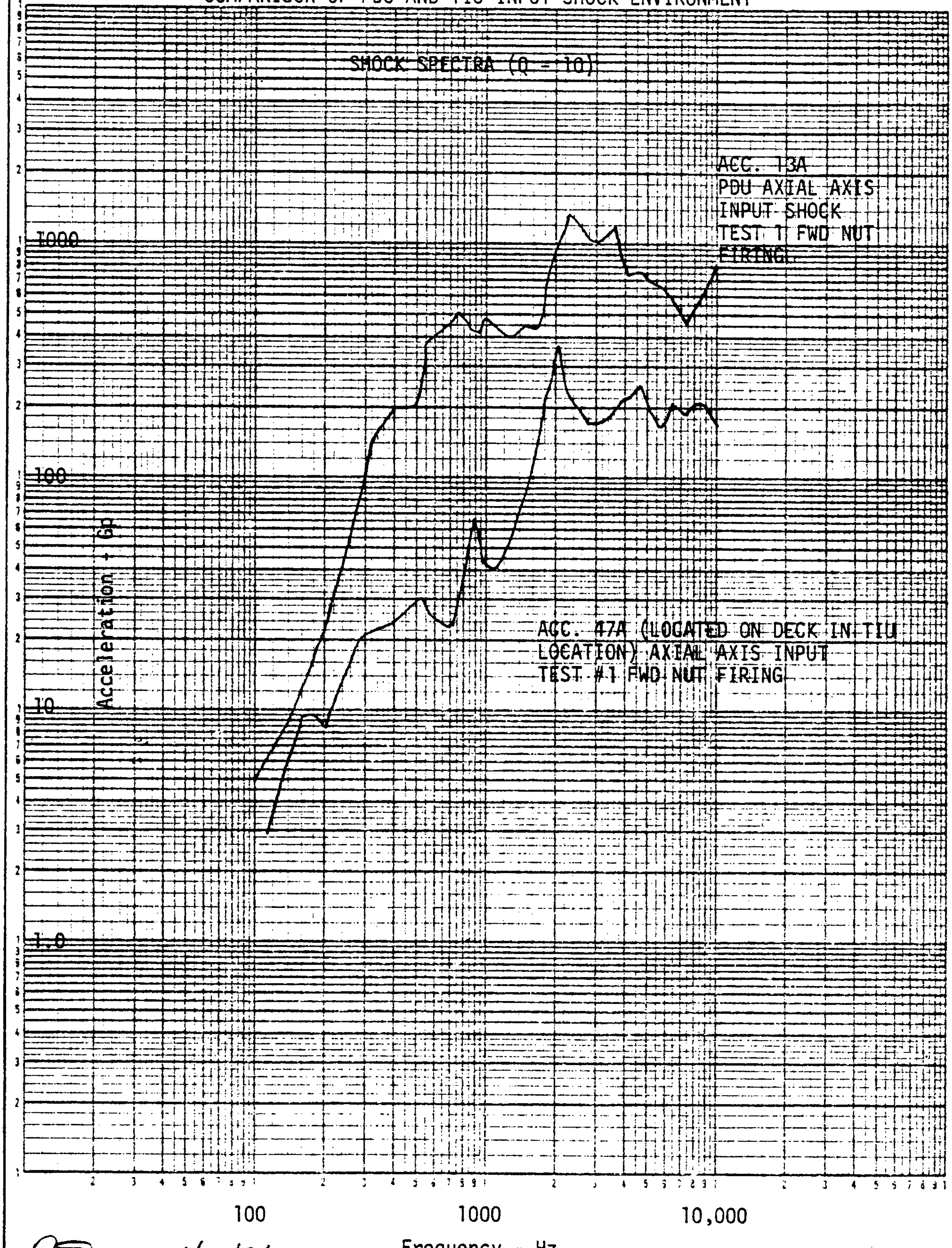

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Figure 3.3.2.2-6
PDU ESS Deck Vibration Isolator

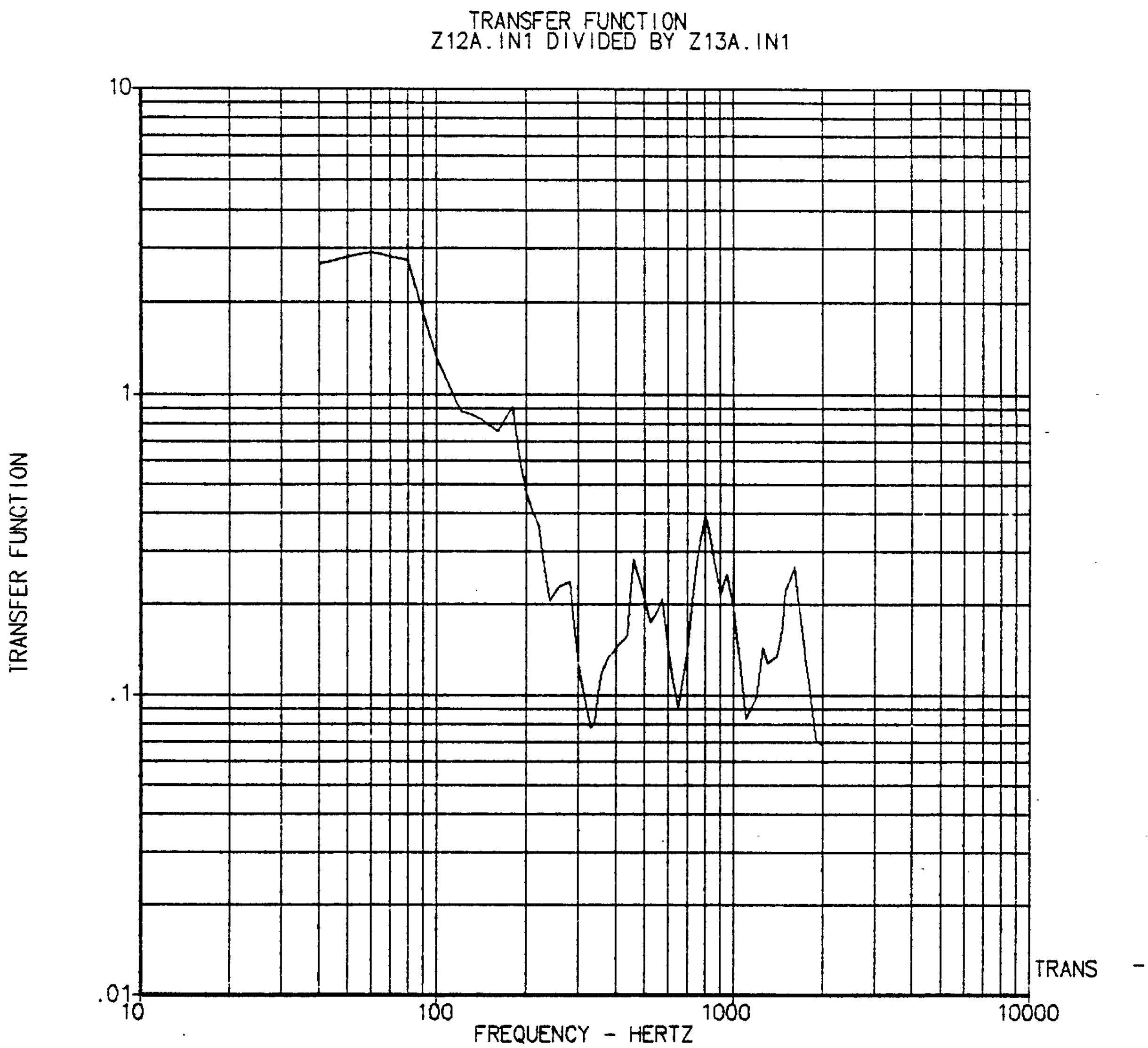

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Figure 3.3.2.2-7

PDU ESS Deck Vibration Isolator

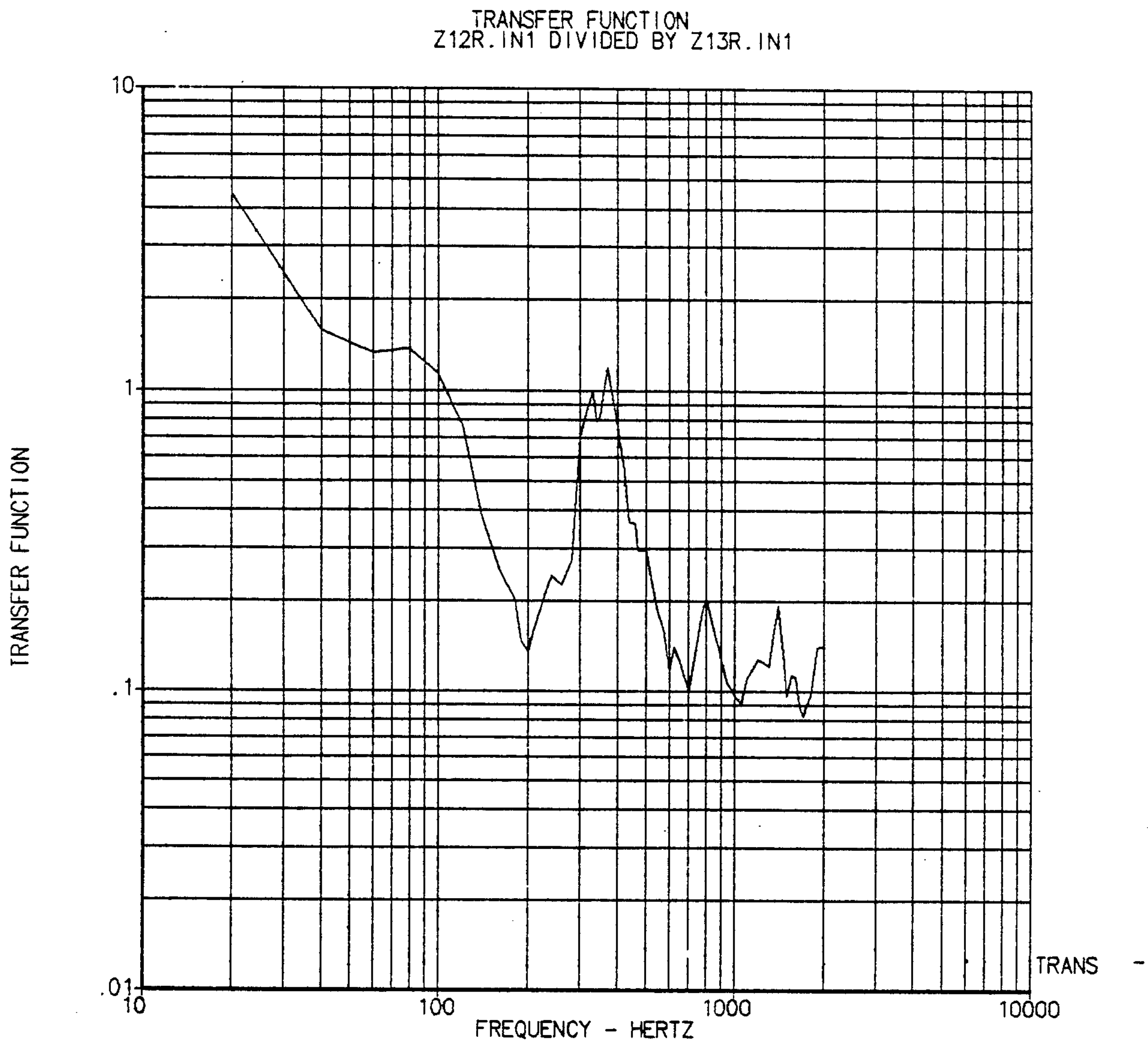
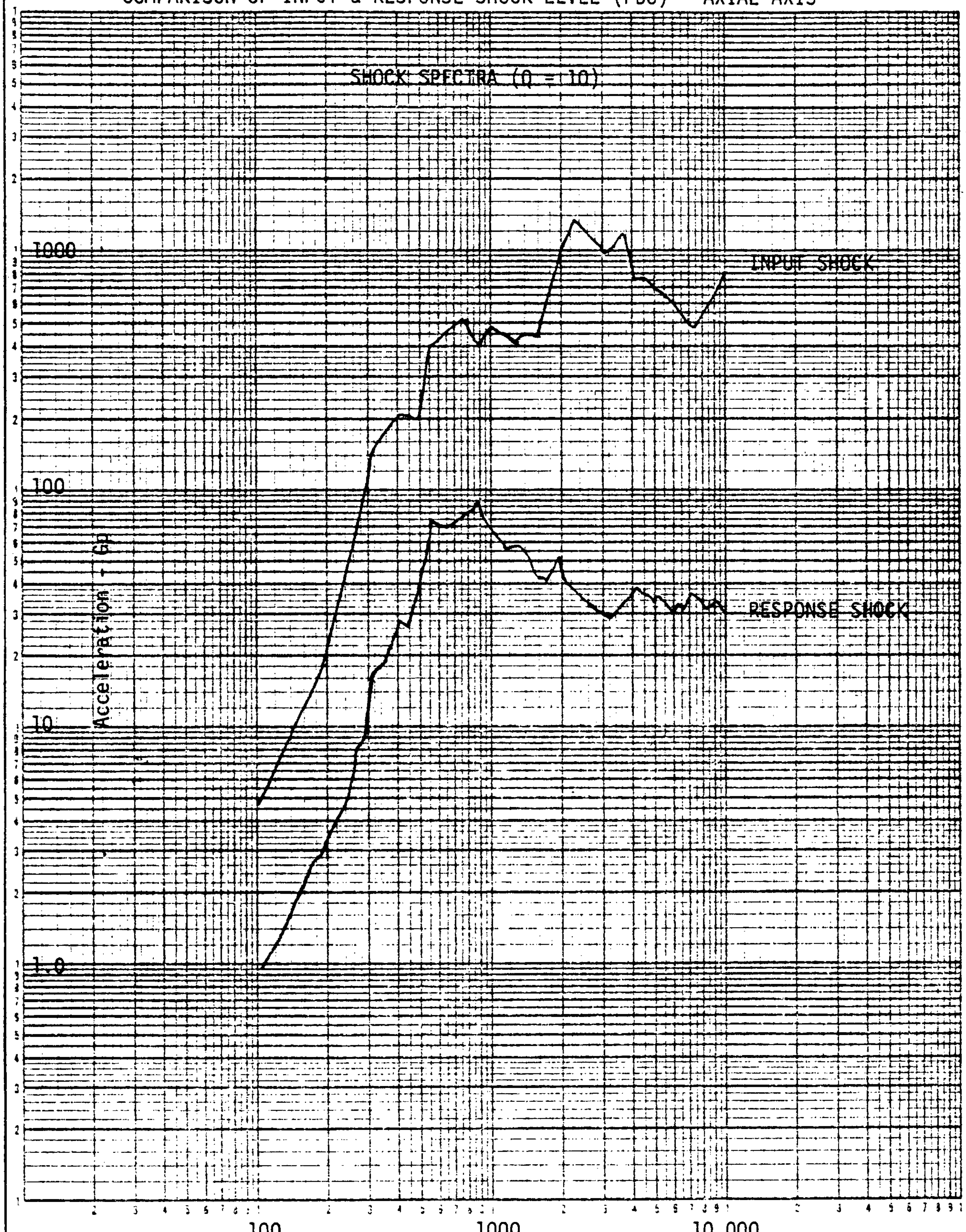


Figure 3.3.2.2-8

COMPARISON OF INPUT & RESPONSE SHOCK LEVEL (PDU) AXIAL AXIS



Fran 1/16/81

Figure 3.3.2.2-9

COMPARISON OF INPUT & RESPONSE SHOCK LEVELS (PDU) RADIAL AXIS

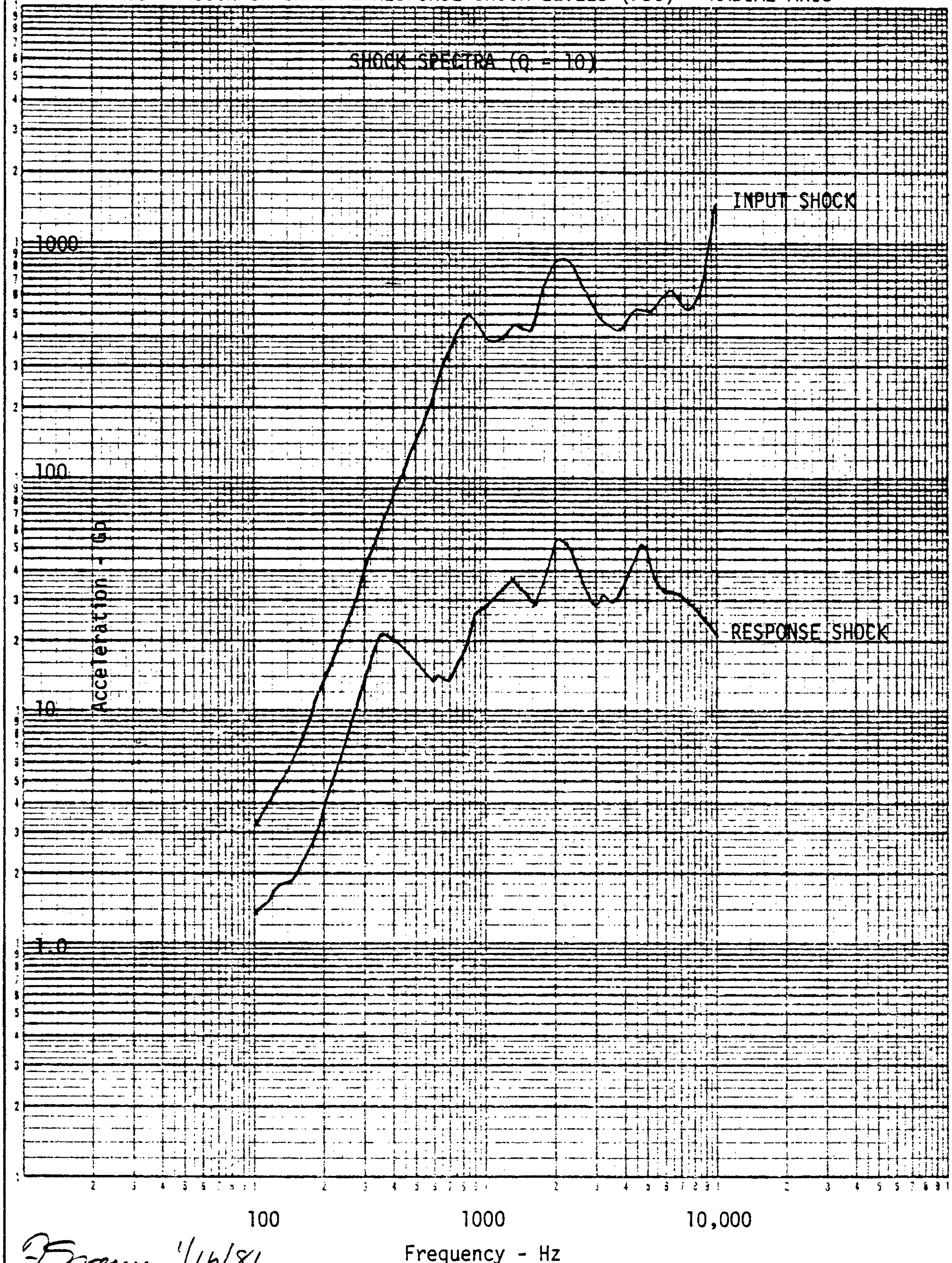


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Figure 3.3.2.2-10

TANGENTIAL AXIS SHOCK MEASURED ON VIBRATION ISOLATED PDU

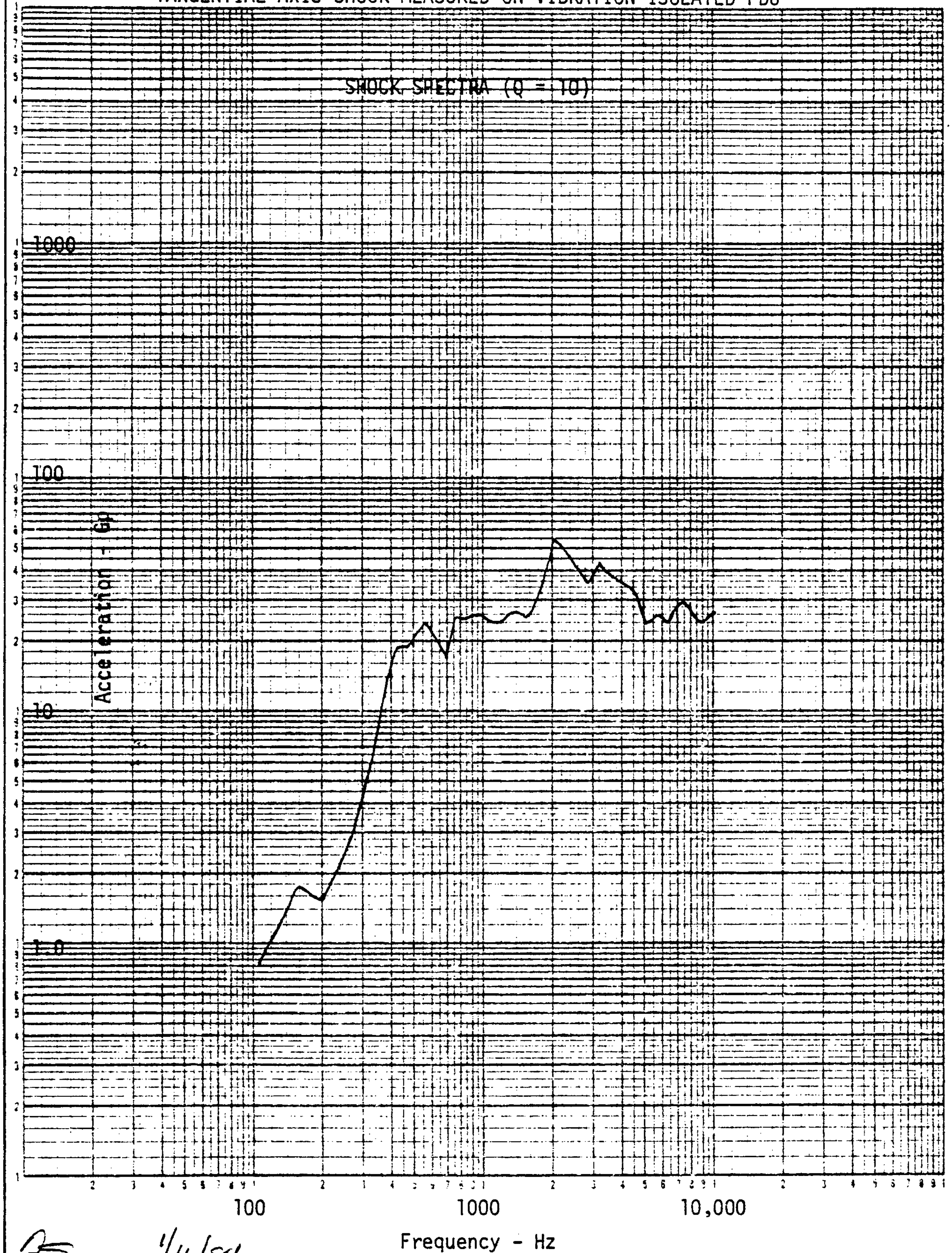

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Figure 3.3.2.2-11

COMPARISON OF TIU CQT REQUIREMENT WITH SHOCK ENVIRONMENT

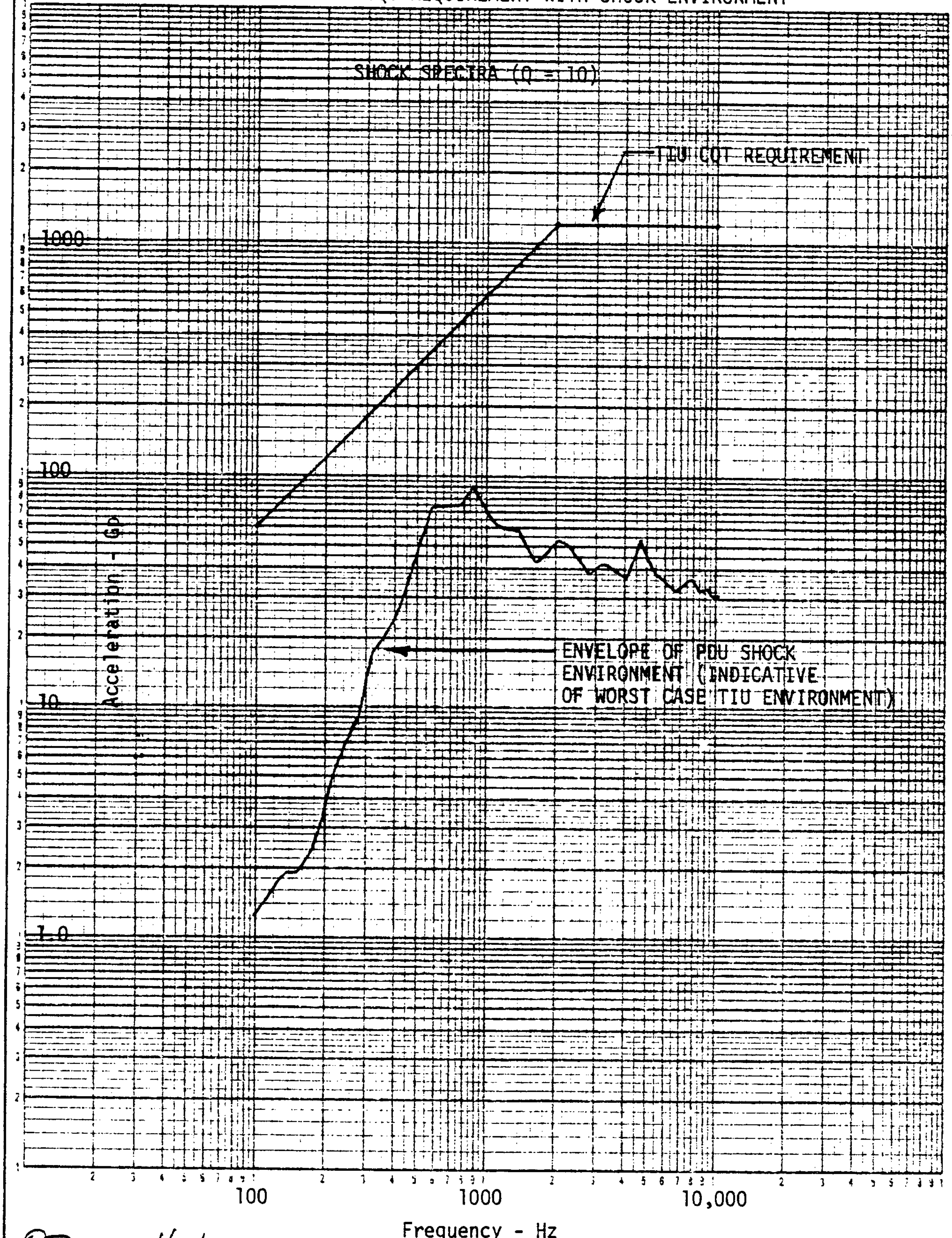

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Figure 4.1-1

T34D/IUS INTERFACE SHOCK SPECTRUM FOR IUS SEPARATION

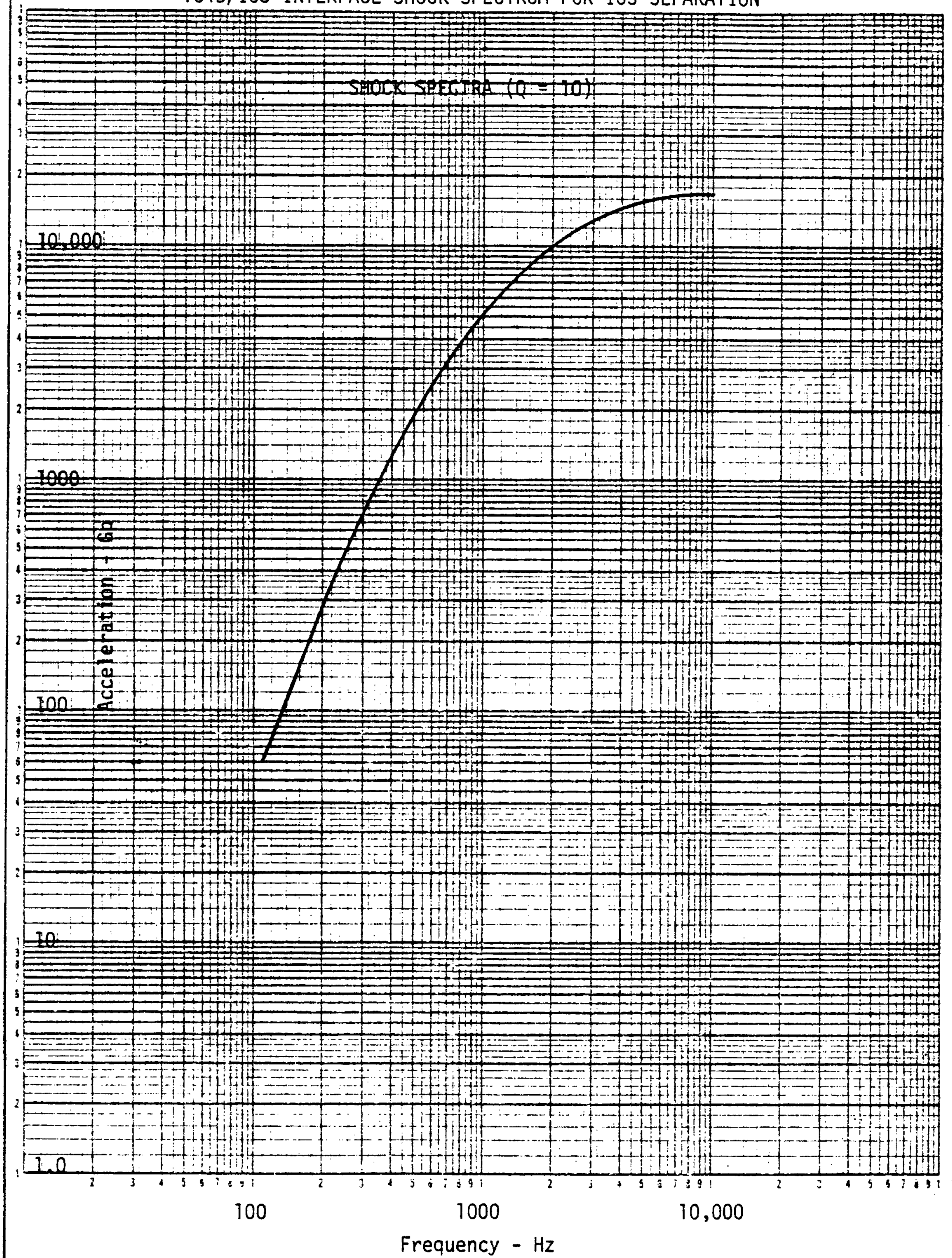
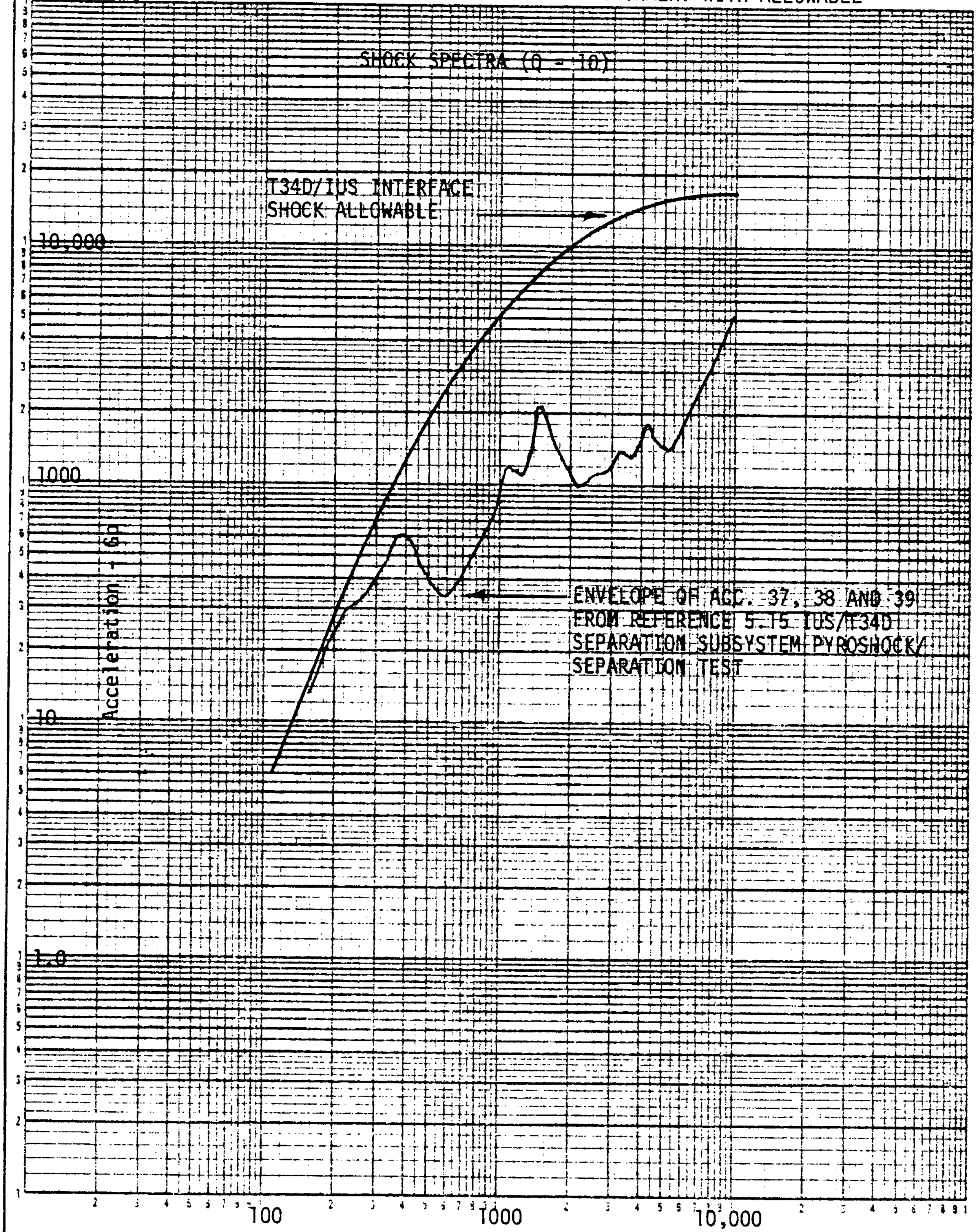


Figure 4.1-2

COMPARISON OF T34D/IUS INTERFACE SHOCK ENVIRONMENT WITH ALLOWABLE



F. Evans 1/16/81

Figure 4.2.1-1

Statistics for 3 Shock Spectra (Q=10)
AFTA PINPULLER

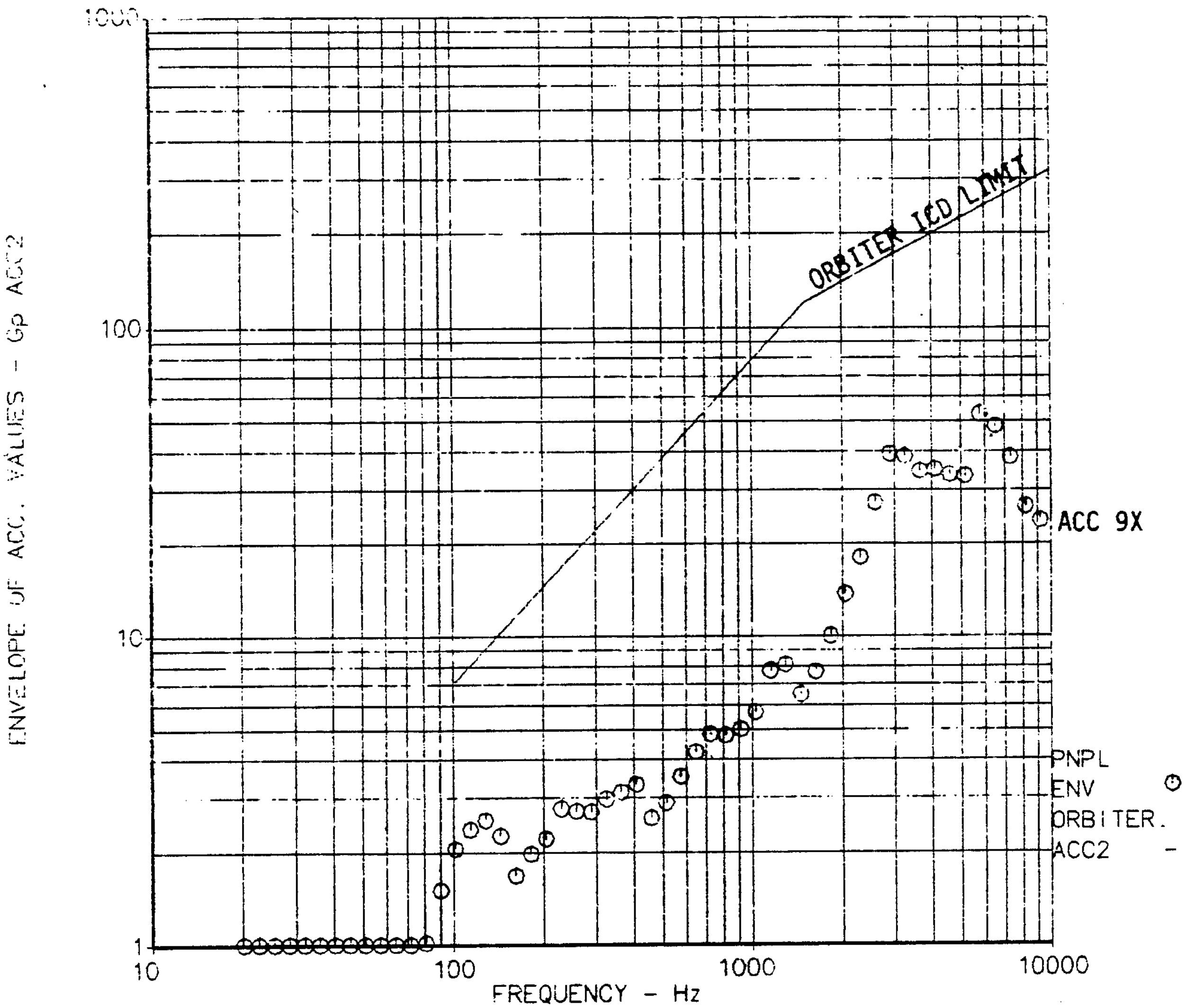


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Figure 4.2.1-2

Statistics for 3 Shock Spectra (Q=10)
AFTA PINPULLER

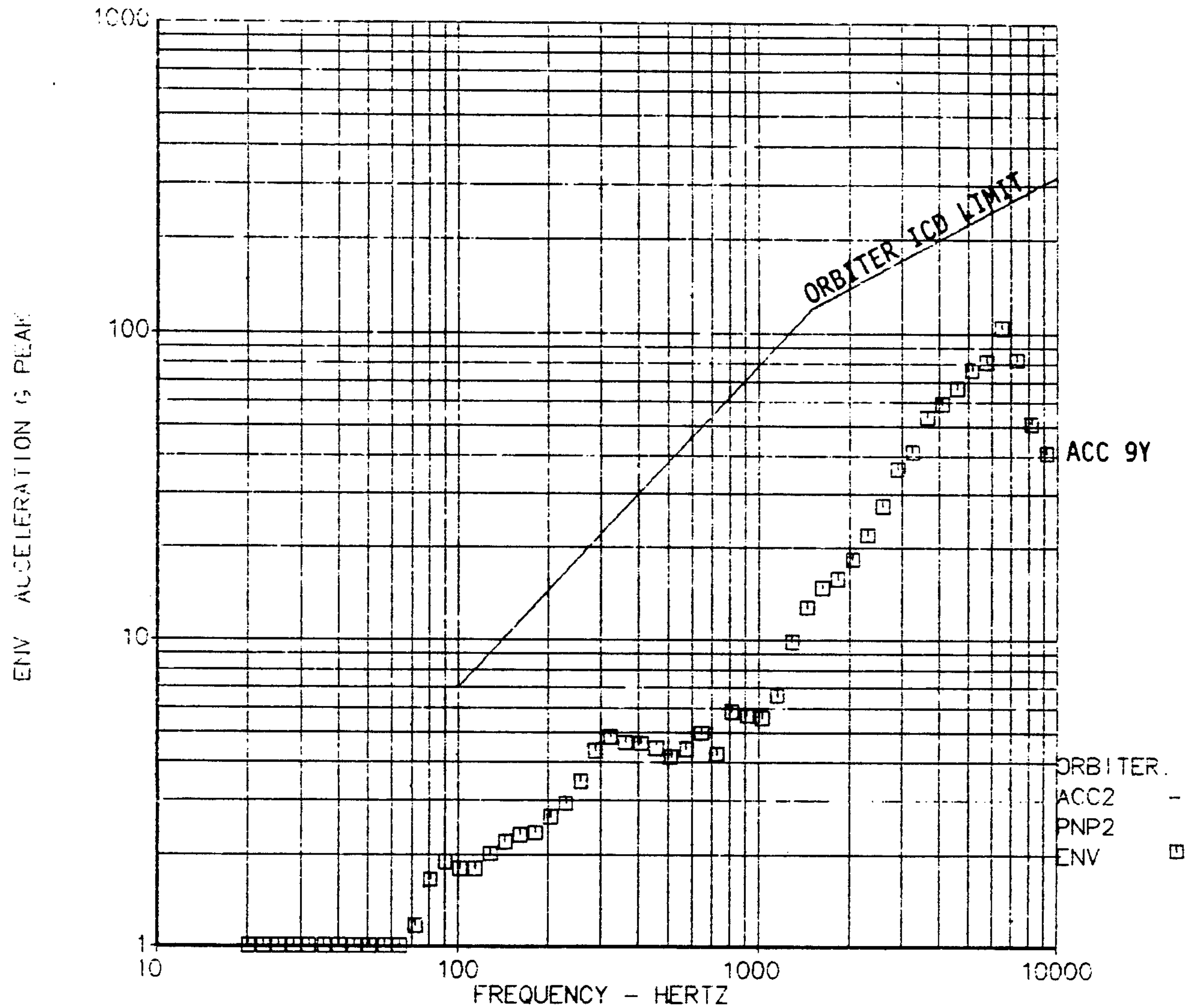

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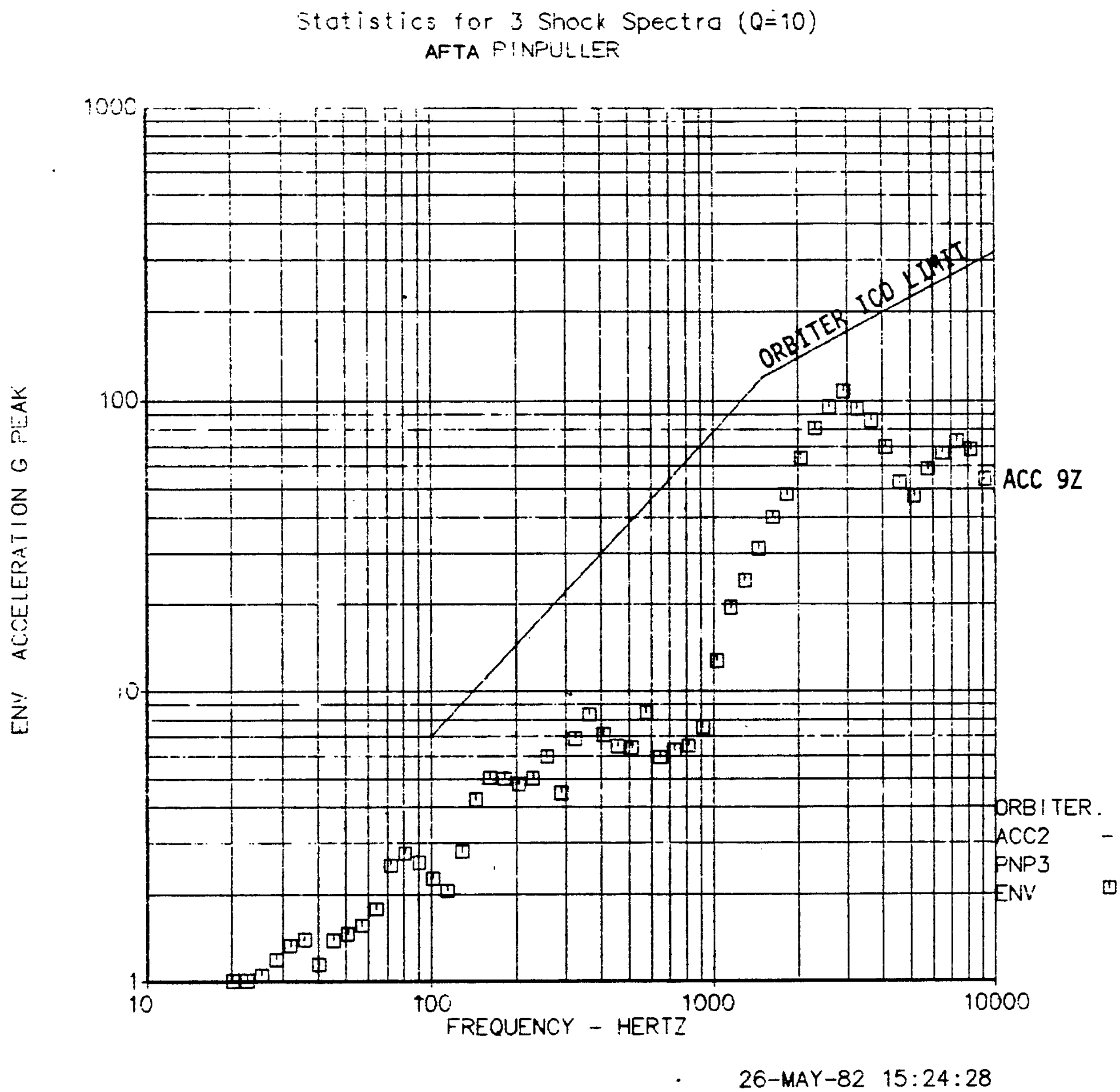
Figure 4.2.1-3



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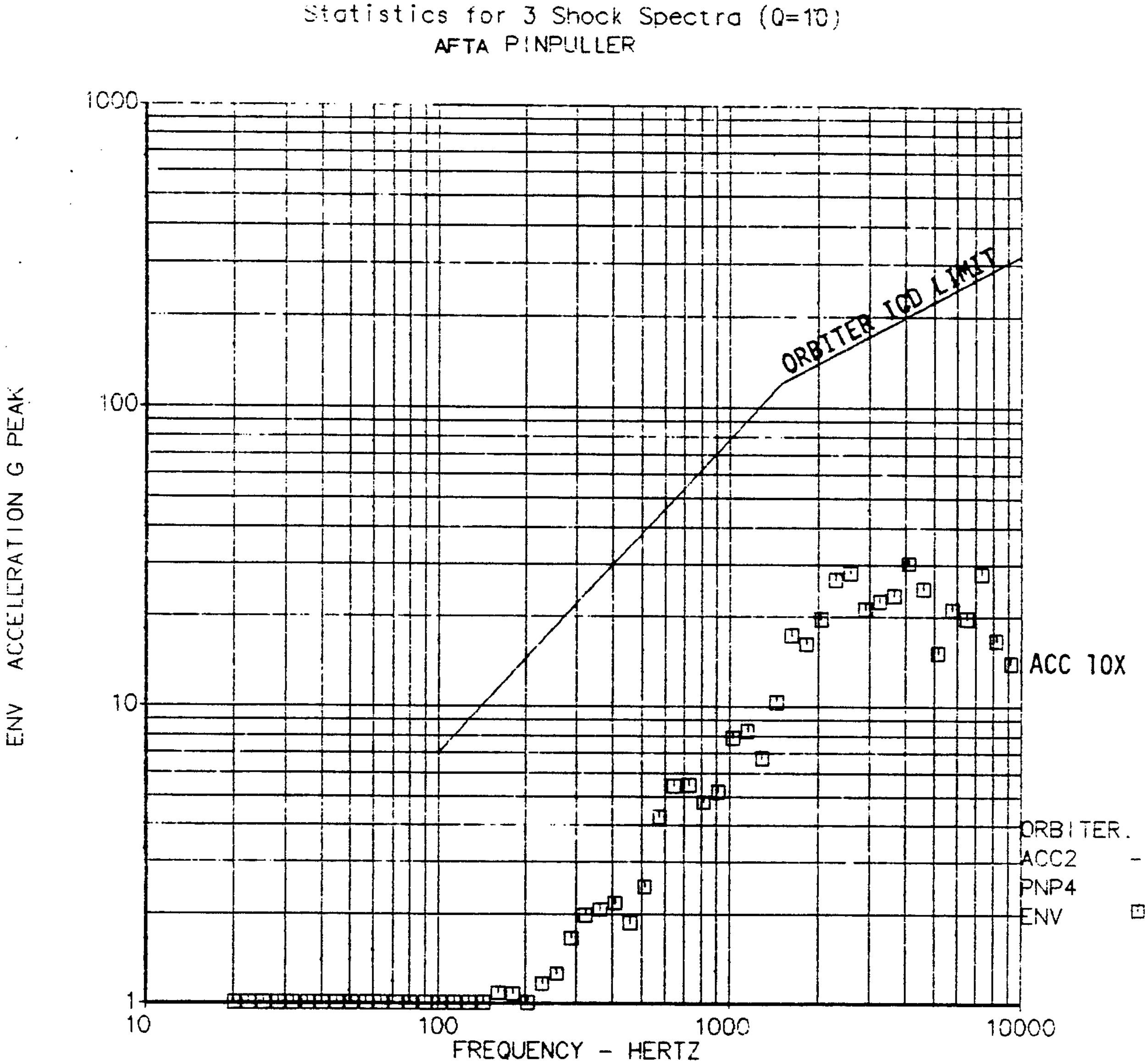

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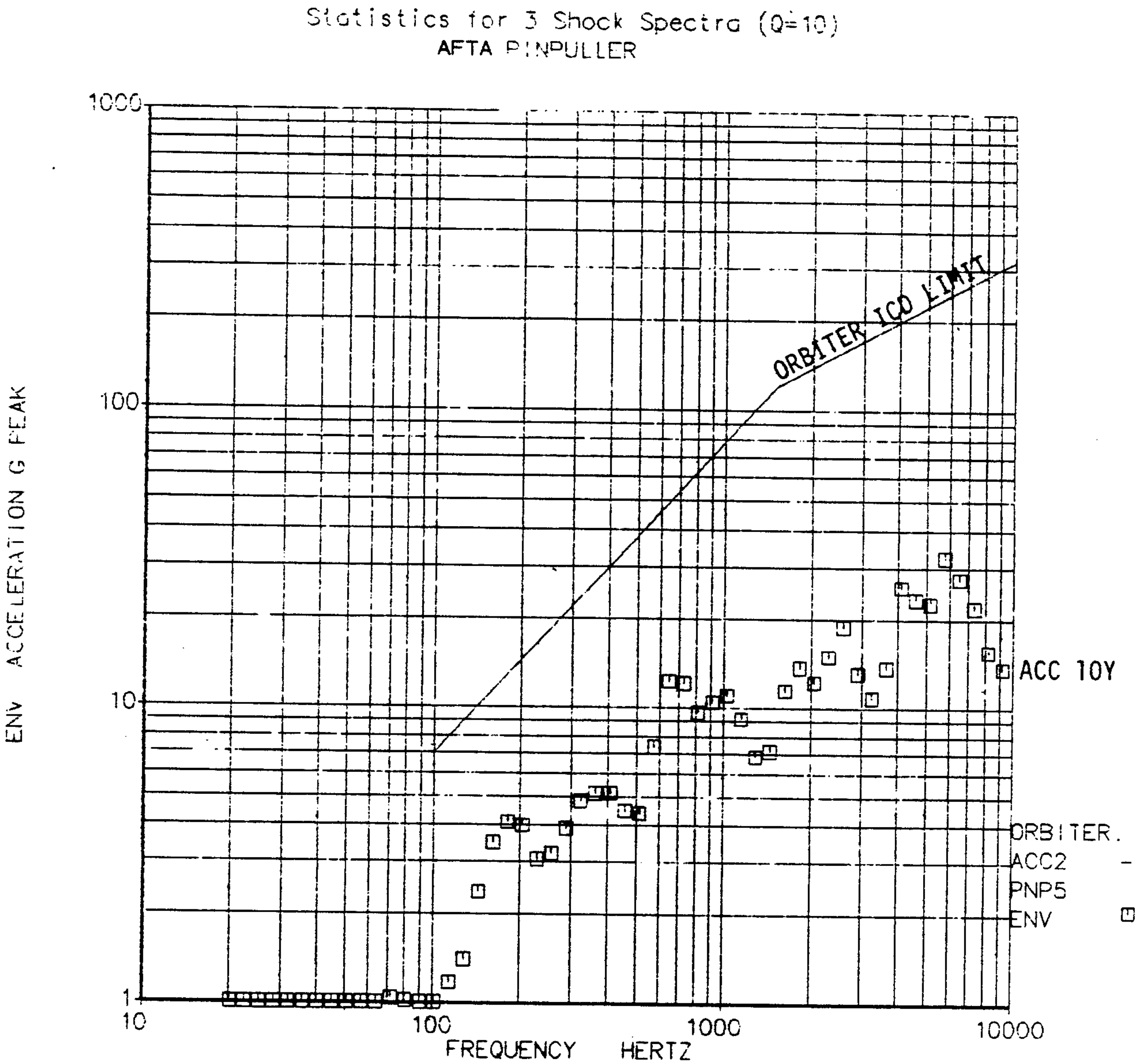

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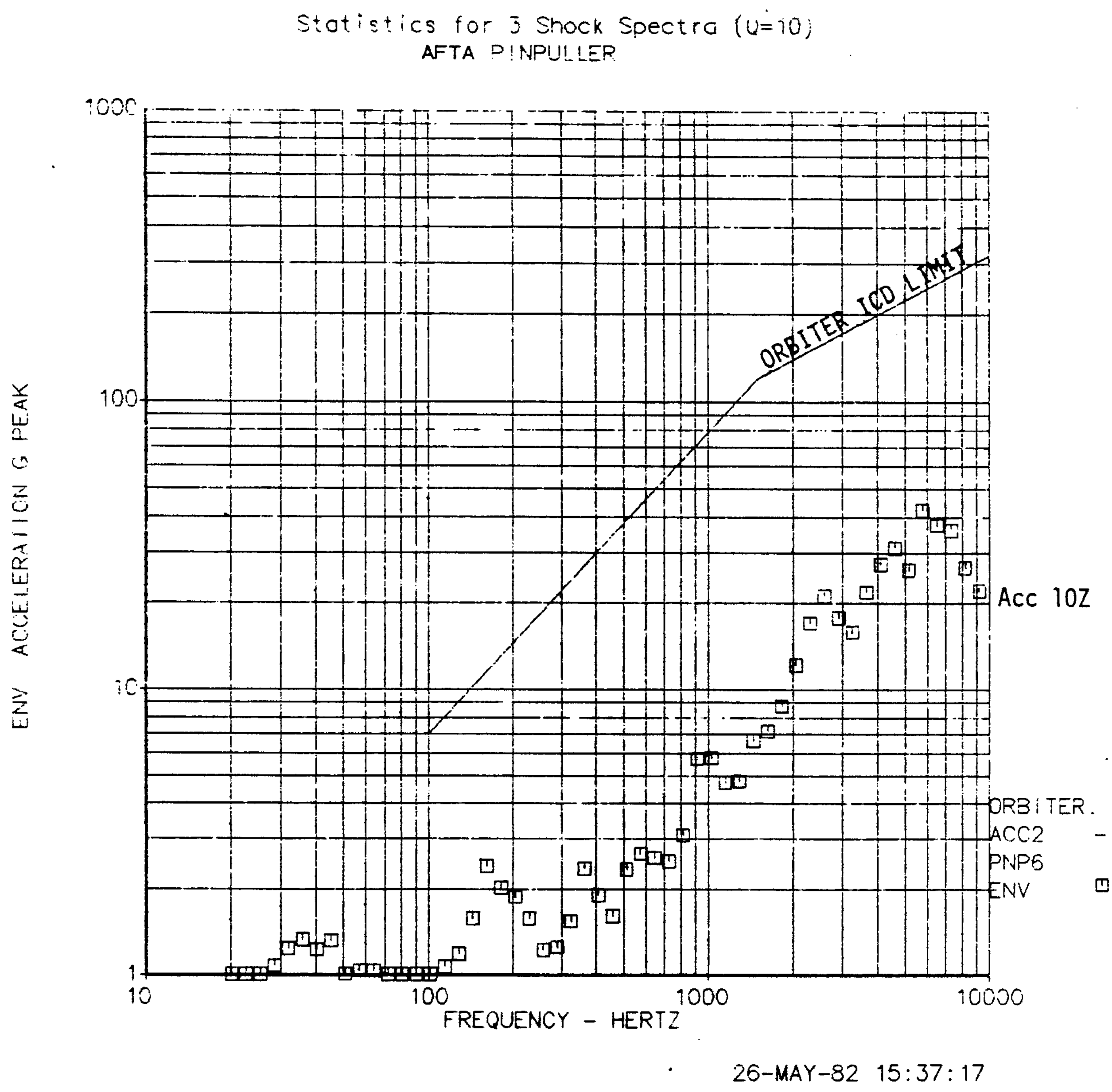
Figure 4.2.1-6



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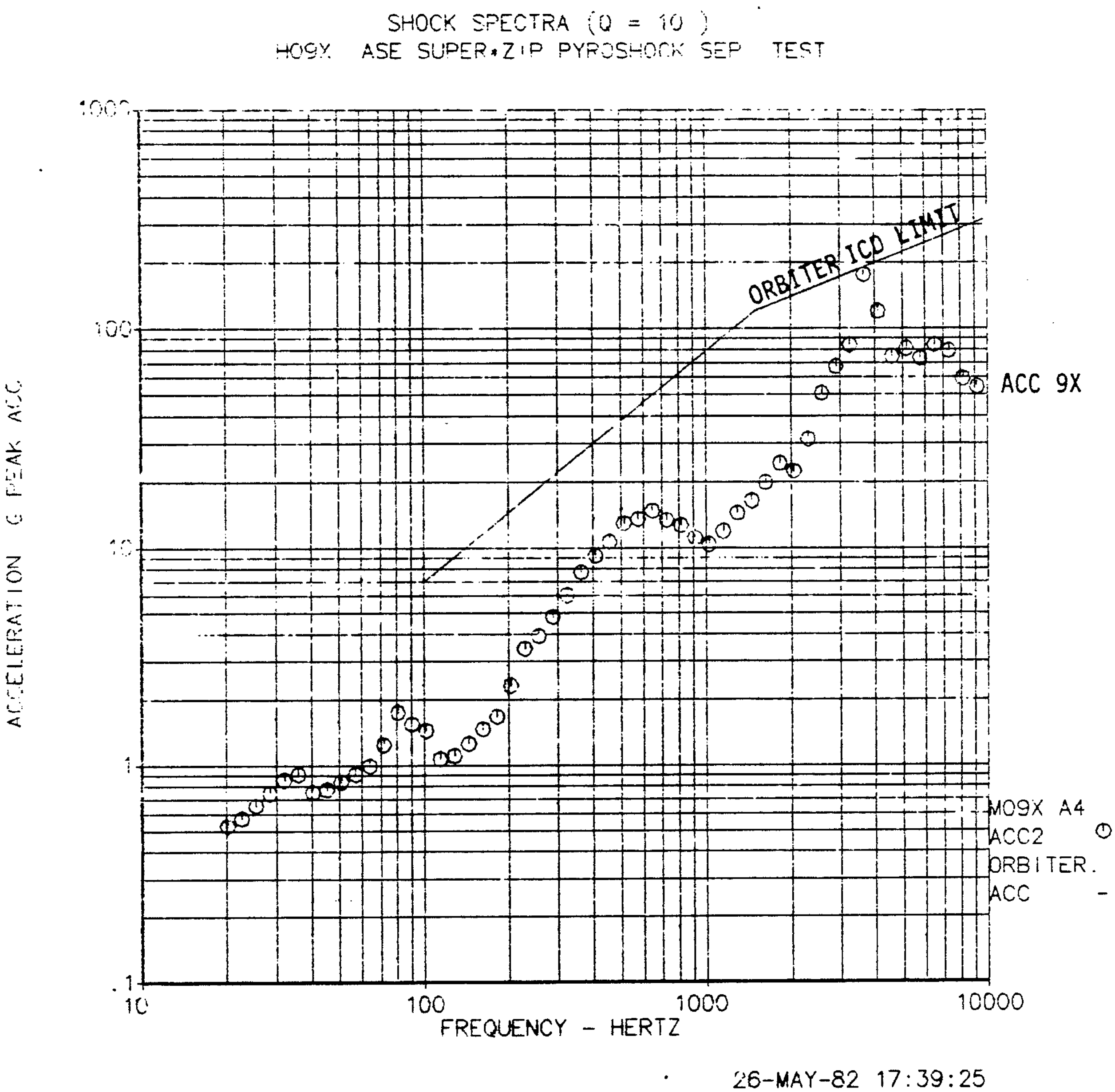

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Figure 4.2.2-2

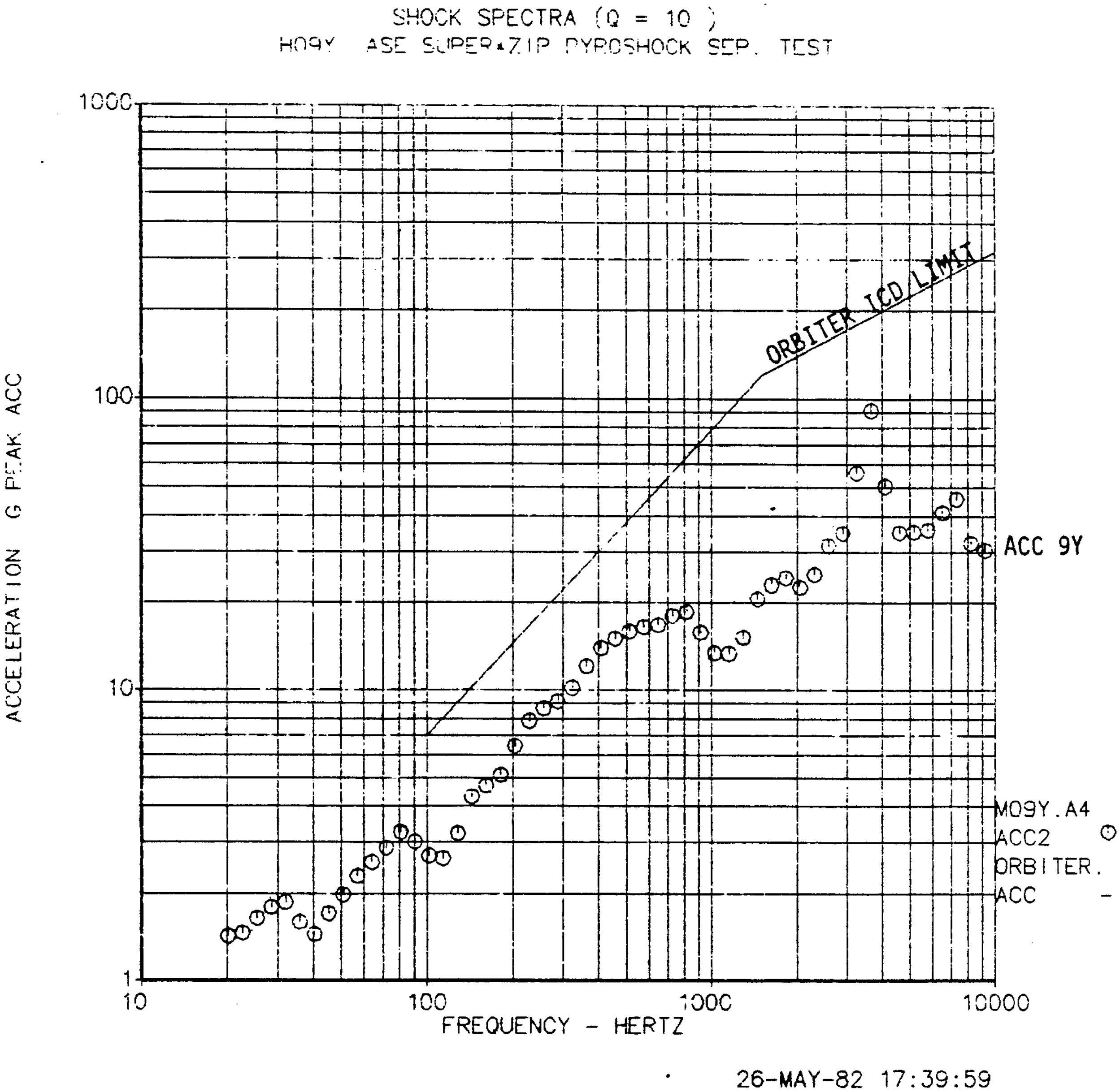

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Figure 4.2.2-3

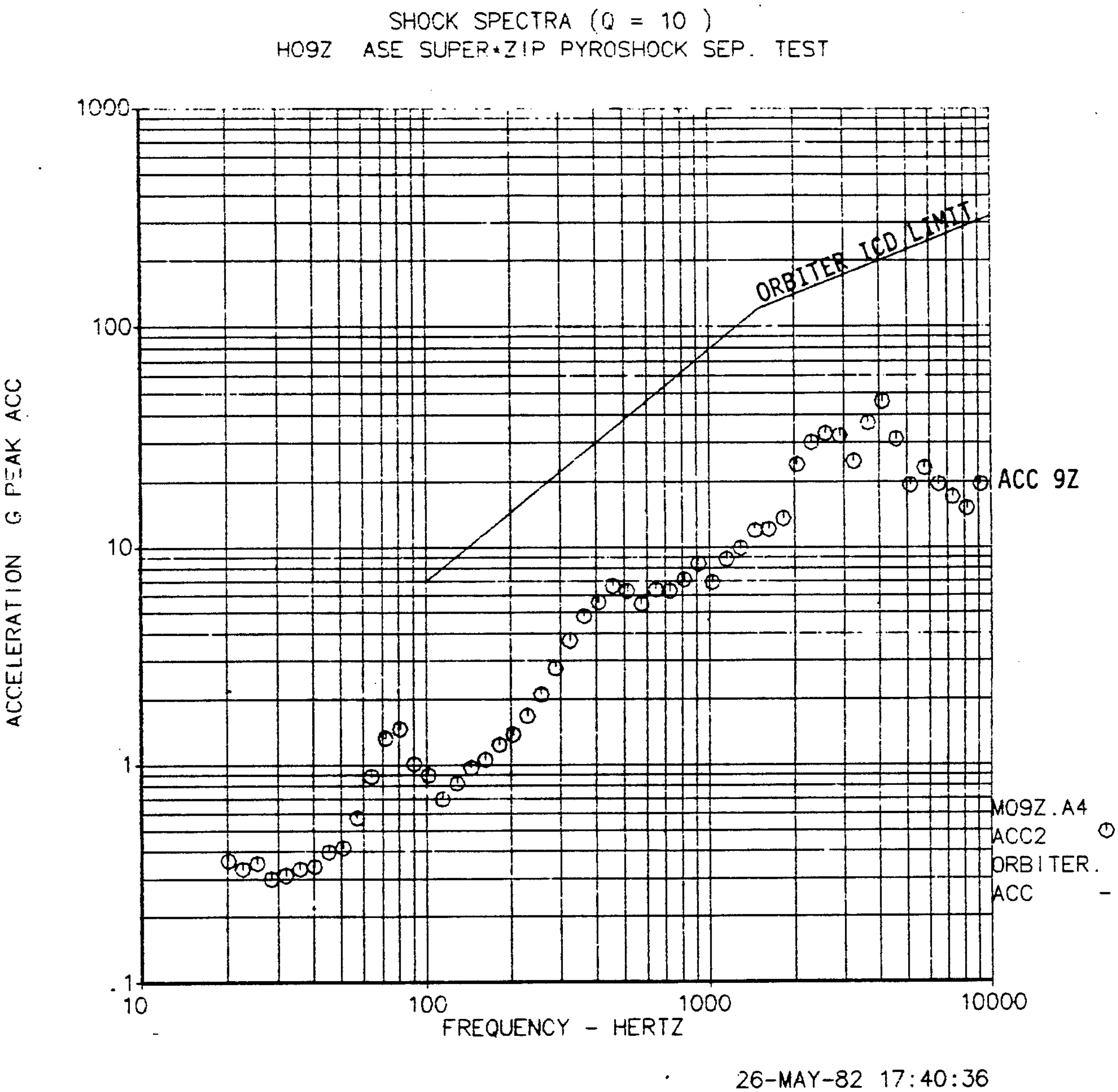

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Figure 4.2.2-4

SHOCK SPECTRA (Q = 10)
H10X ASE SUPER*ZIP PYROSHOCK SEP. TEST

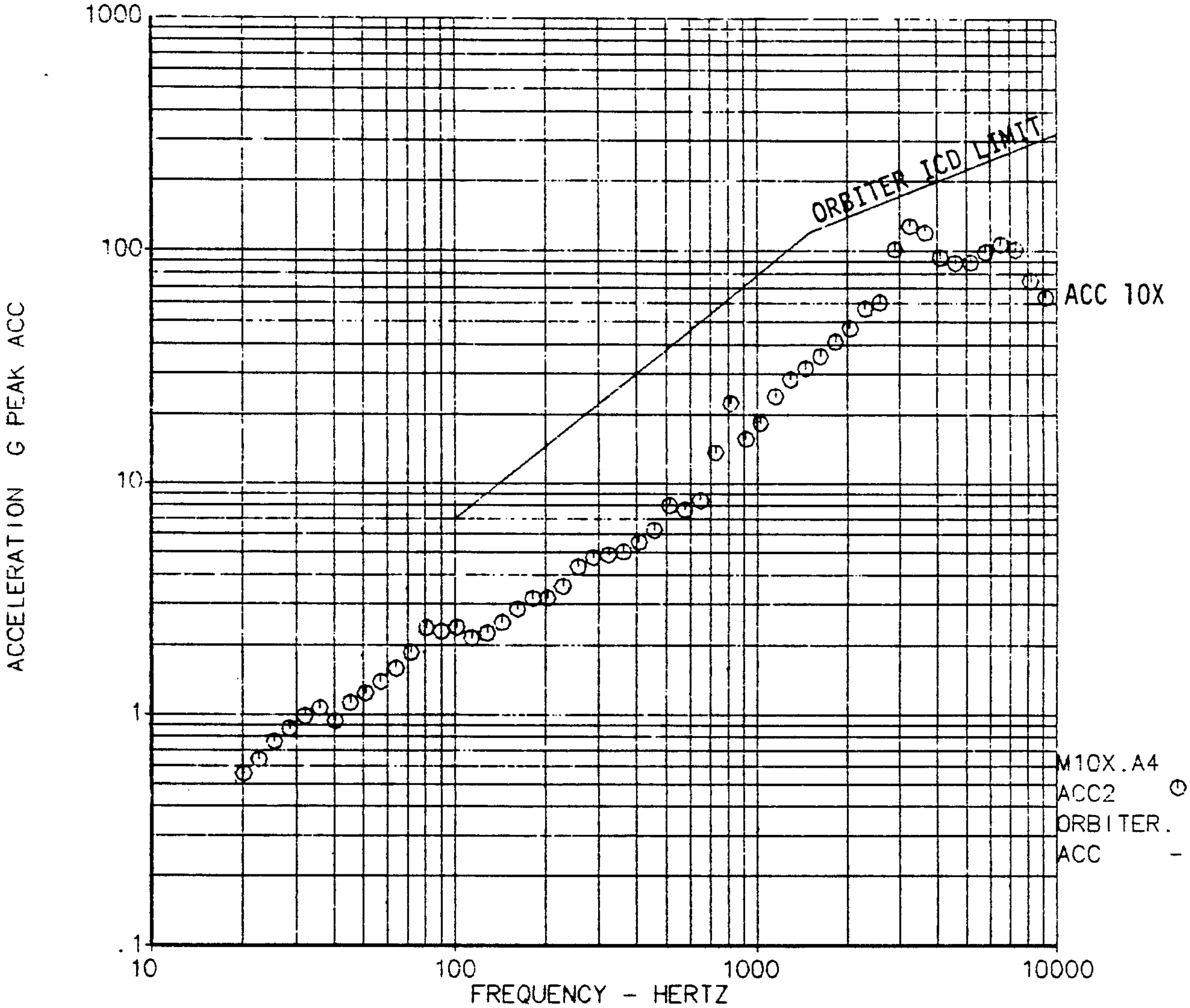

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Figure 4.2.2-5

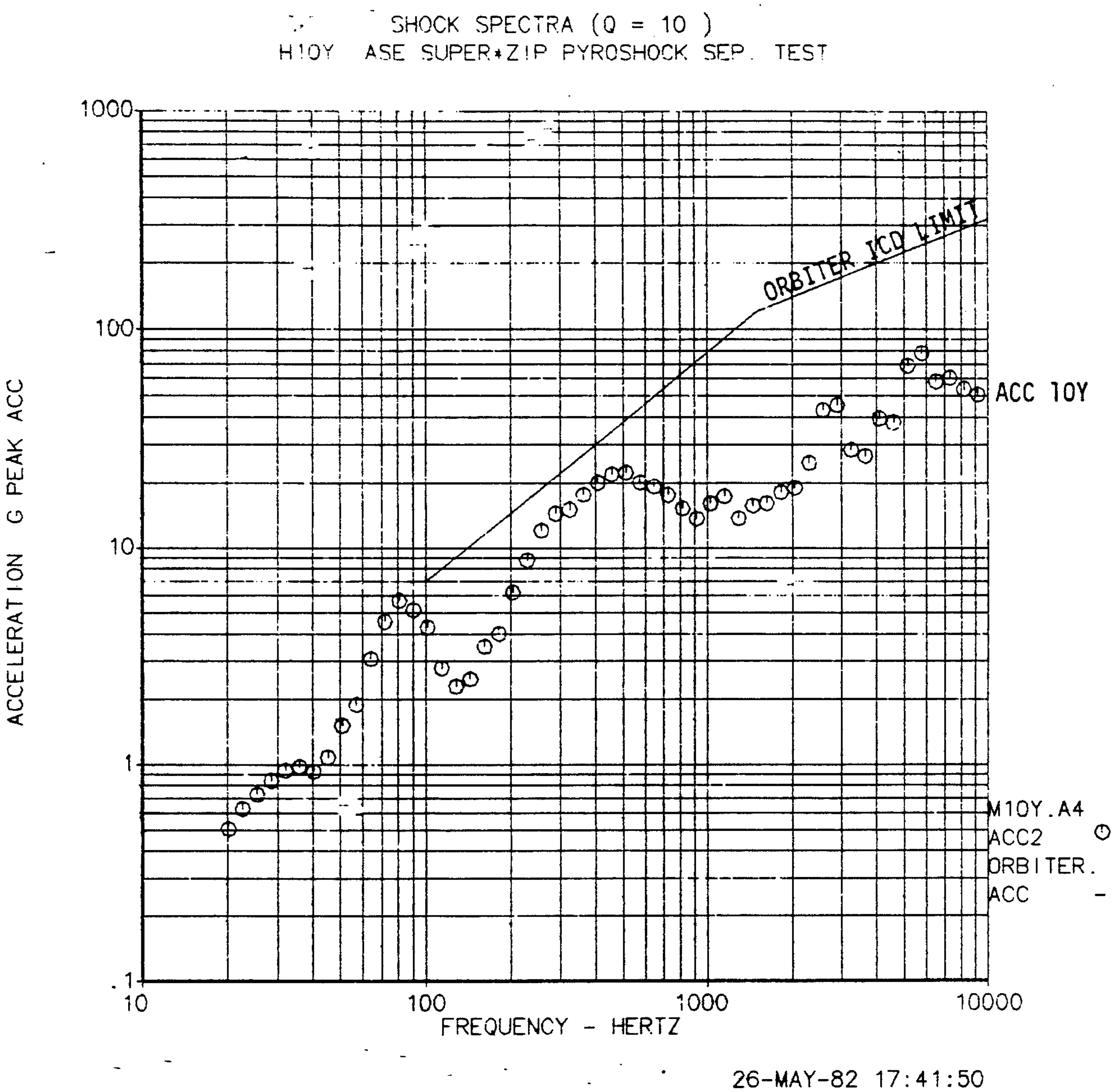

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Figure 4.2.2-6

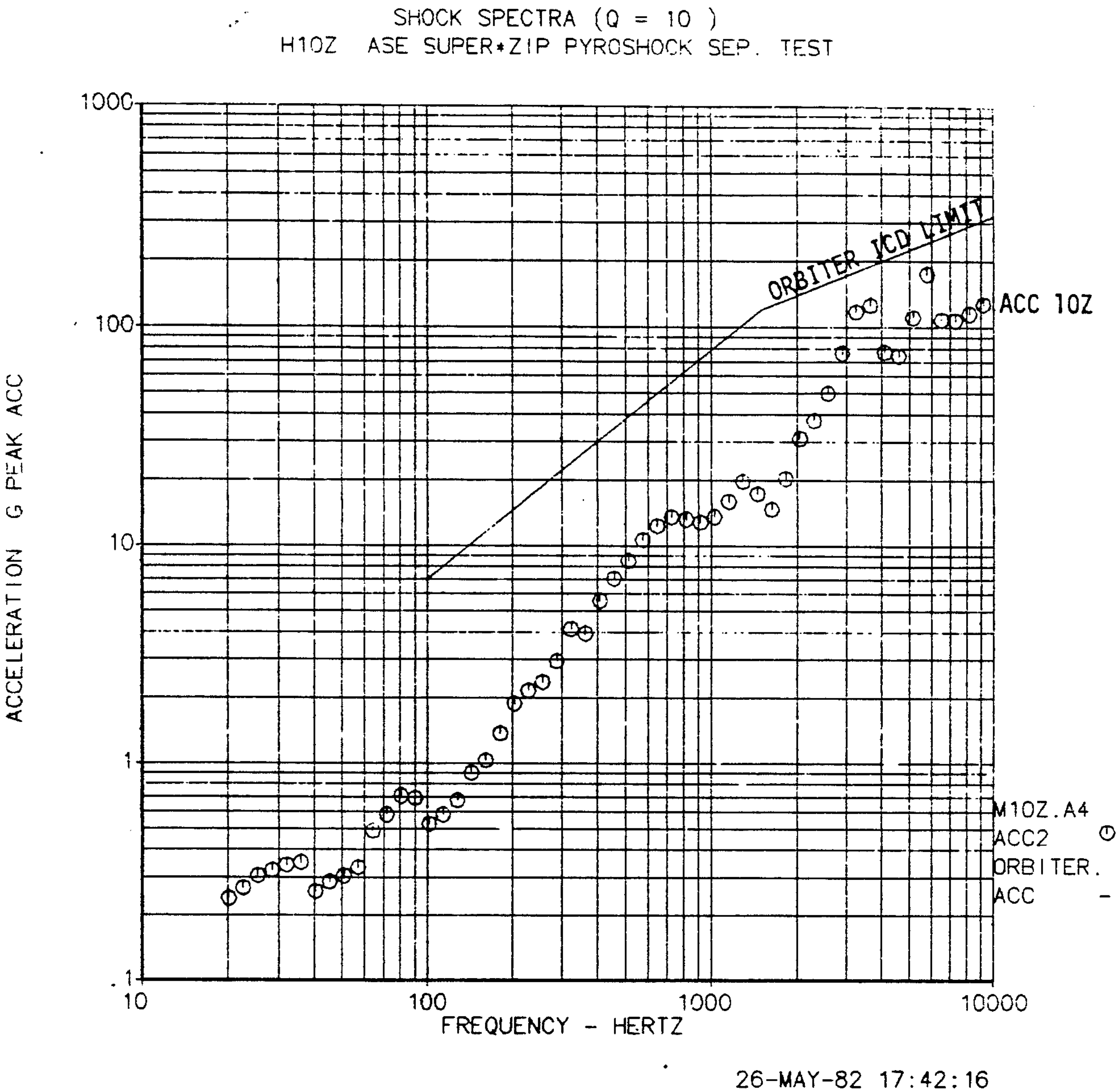

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Figure 4.3-1

IUS INDUCED SHOCK SPECTRA AT IUS-S/C INTERFACE

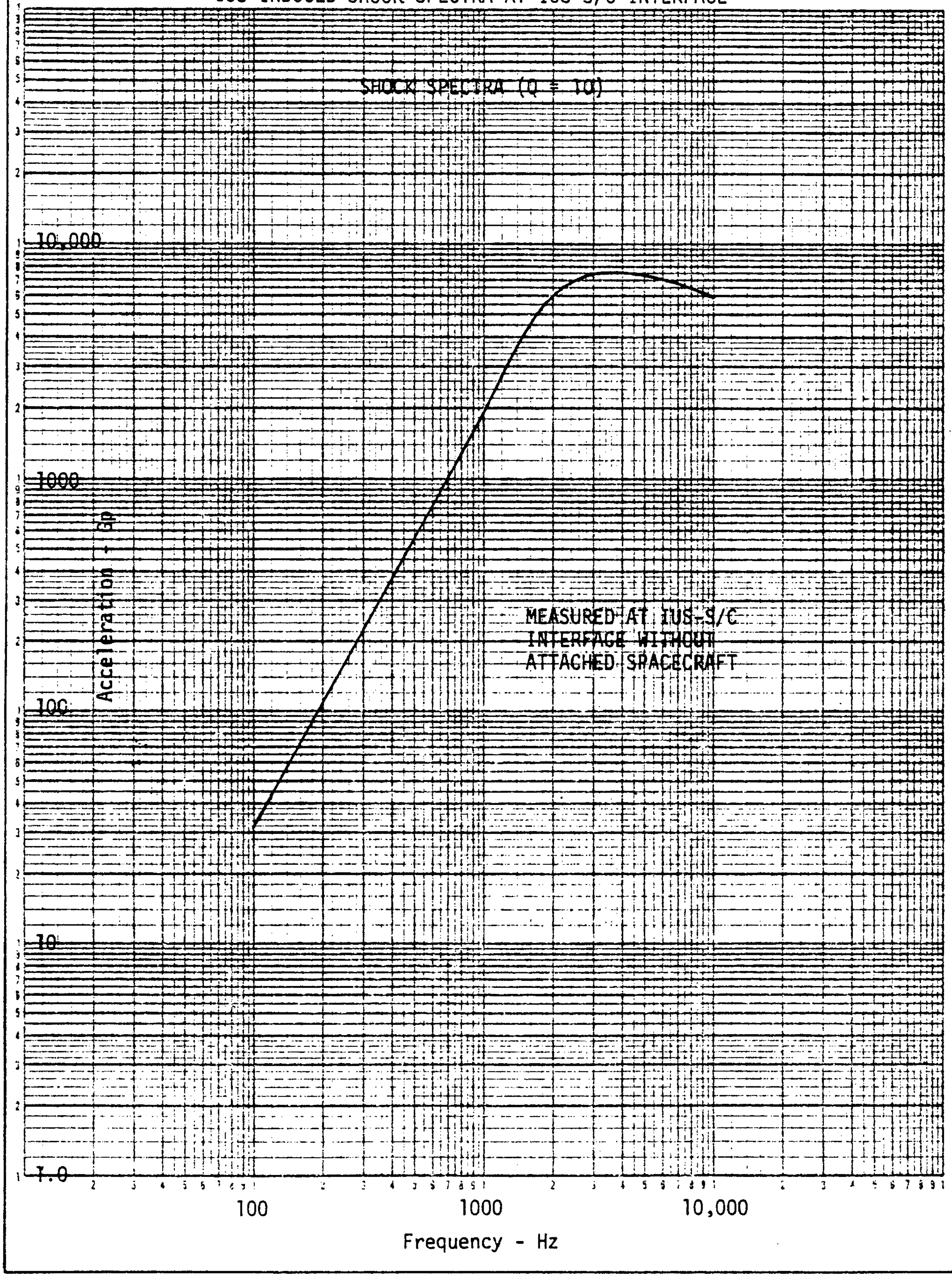
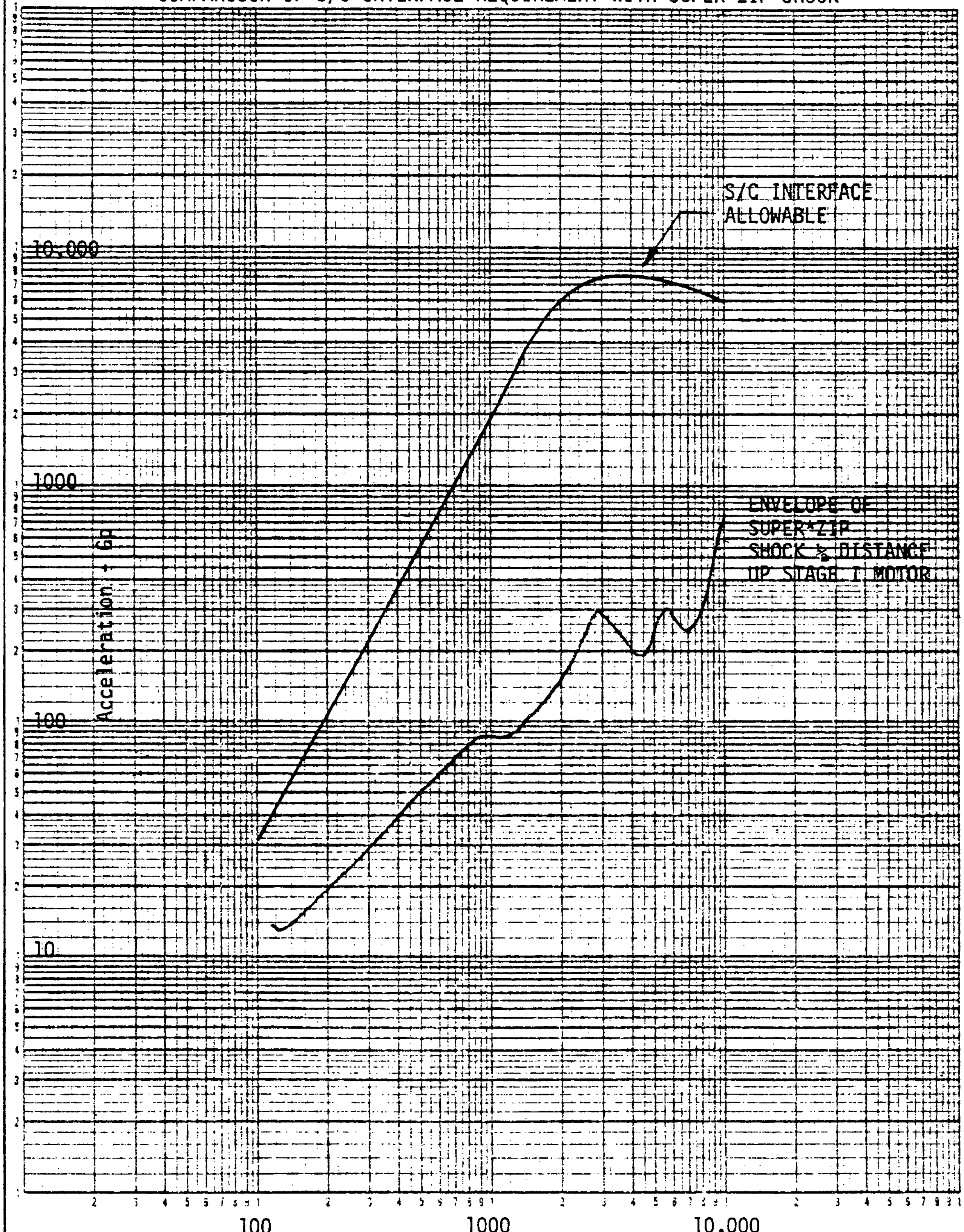


Figure 4.3-2

COMPARISON OF S/C INTERFACE REQUIREMENT WITH SUPER*ZIP SHOCK



F. Zamm 1/16/81

Figure 4.3-3

COMPARISON OF S/C INTERFACE REQUIREMENT WITH S & A SHOCK ENVIRONMENT

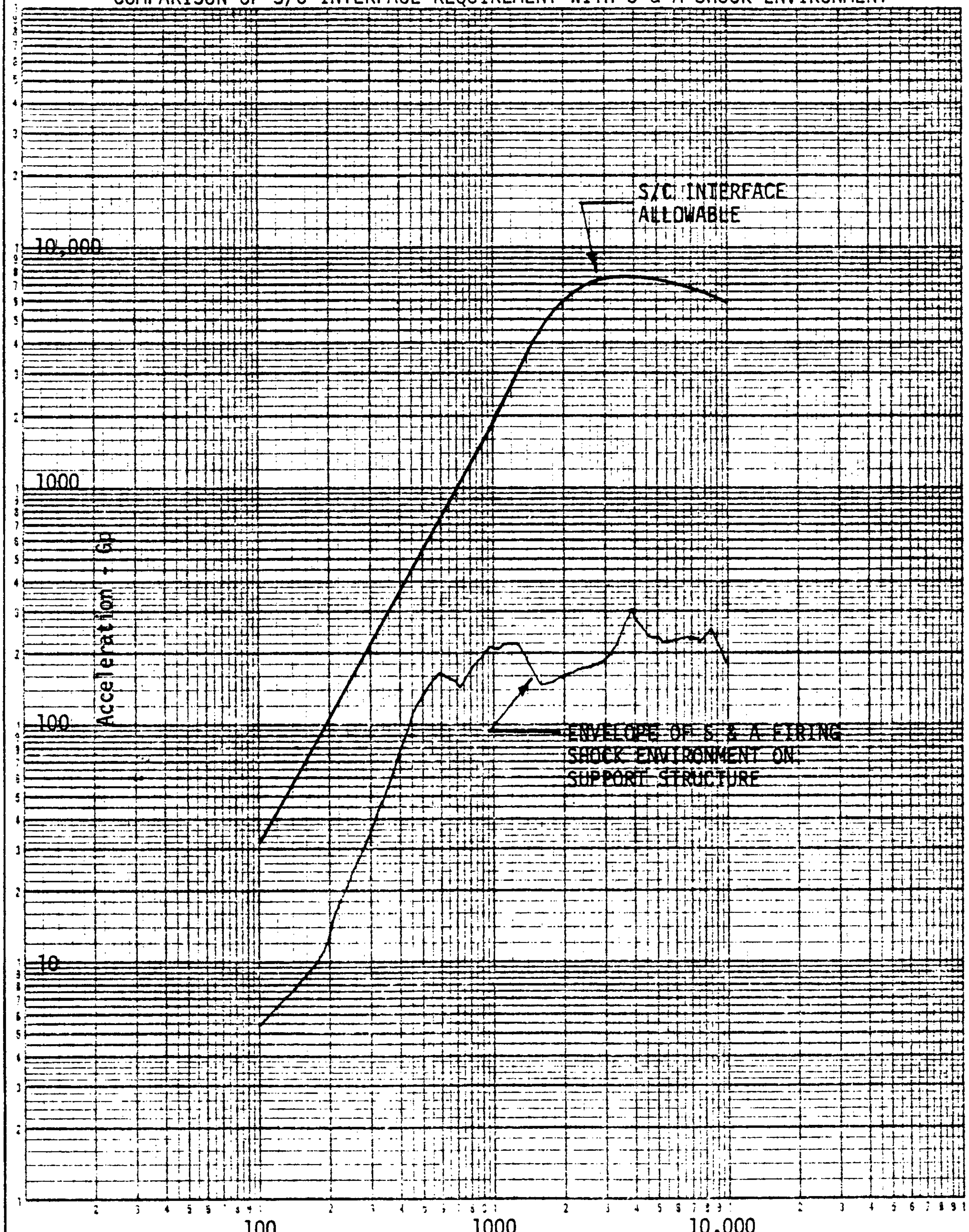


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Figure 4.3-4

Comparison of S/C Interface Allowable Shock with
I/II Staging Separation Shock Environment

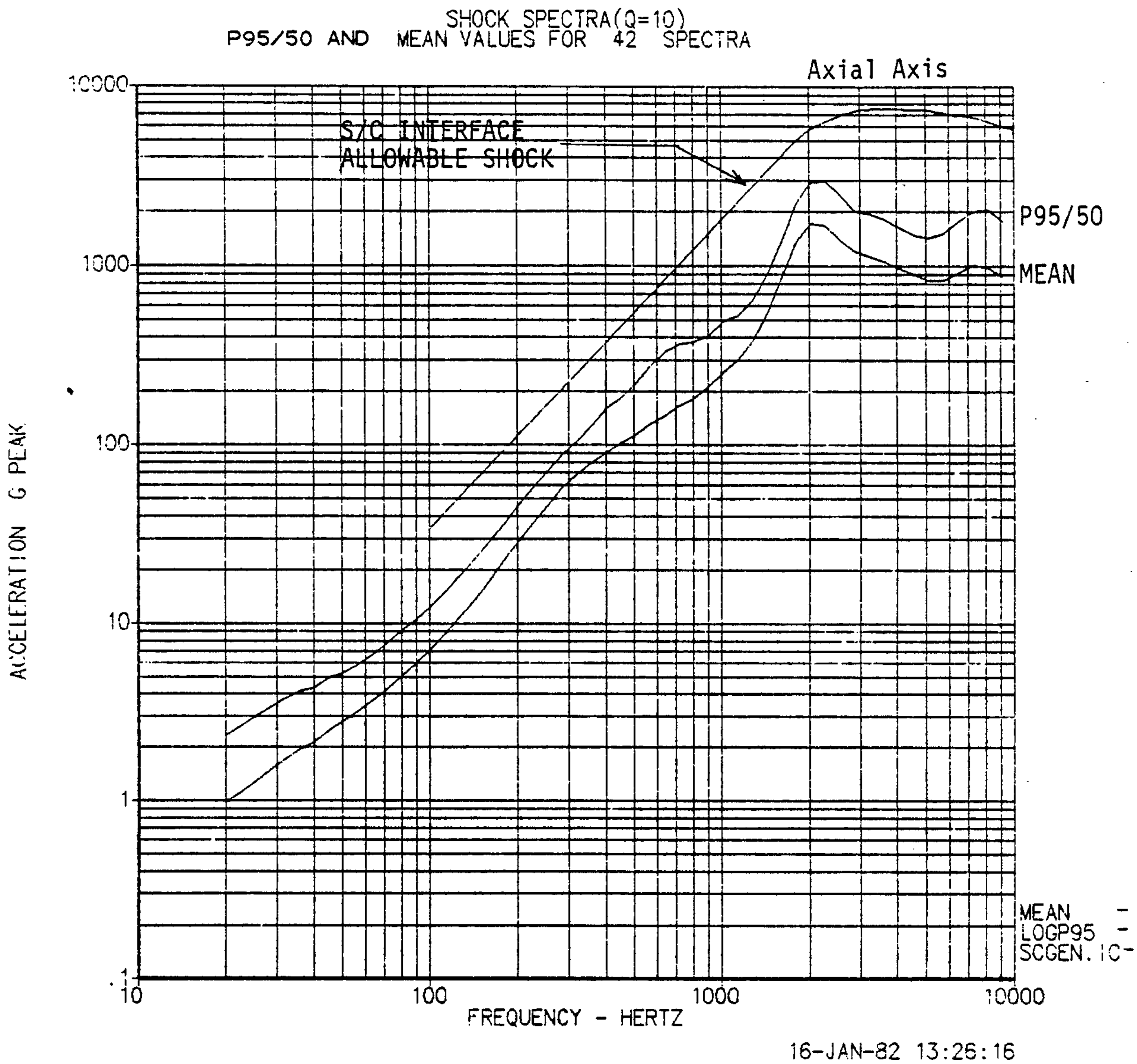

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Figure 4.3-5

Comparison of S/C Interface Allowable Shock with I/II Staging Separation Shock Environment

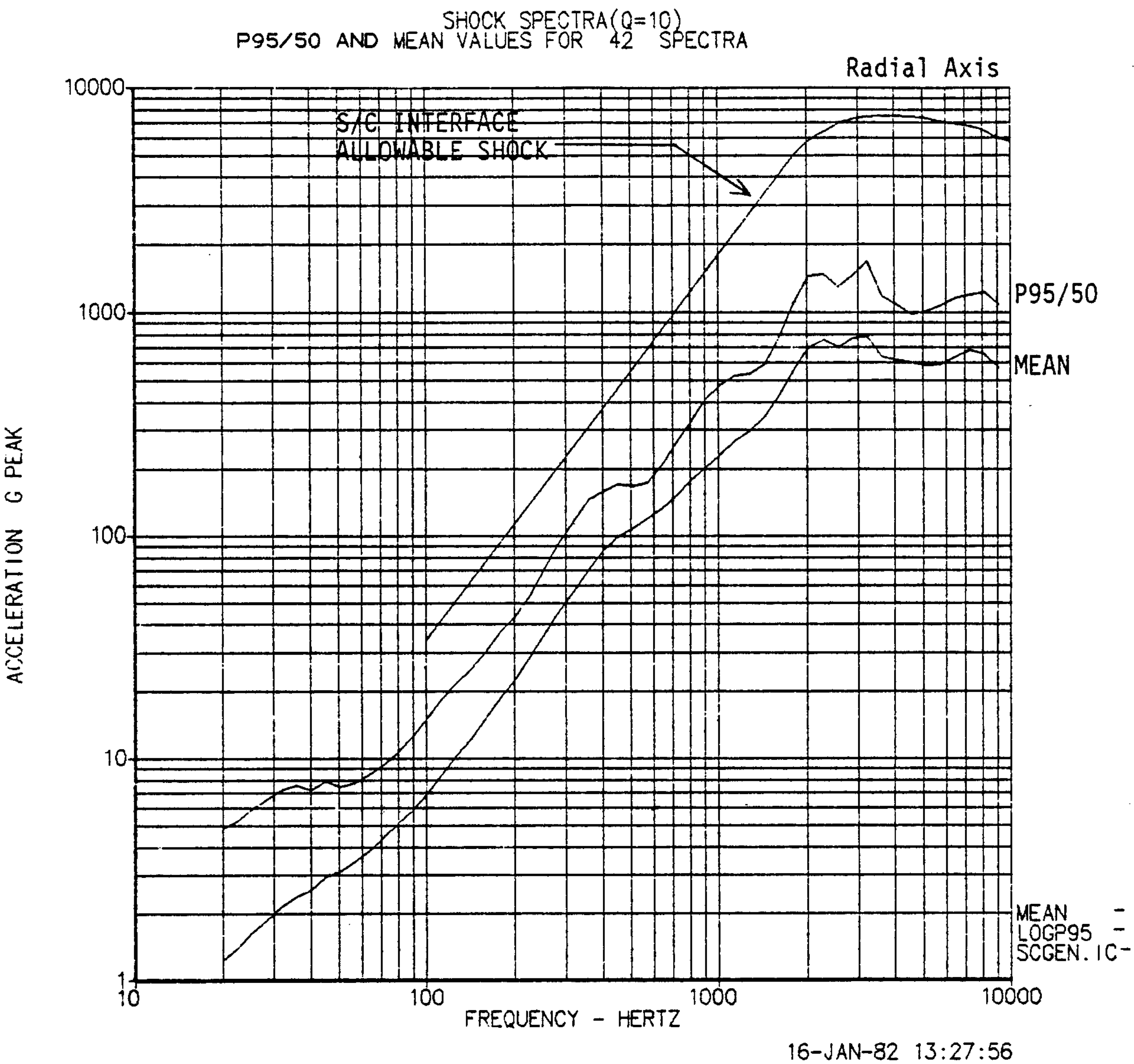
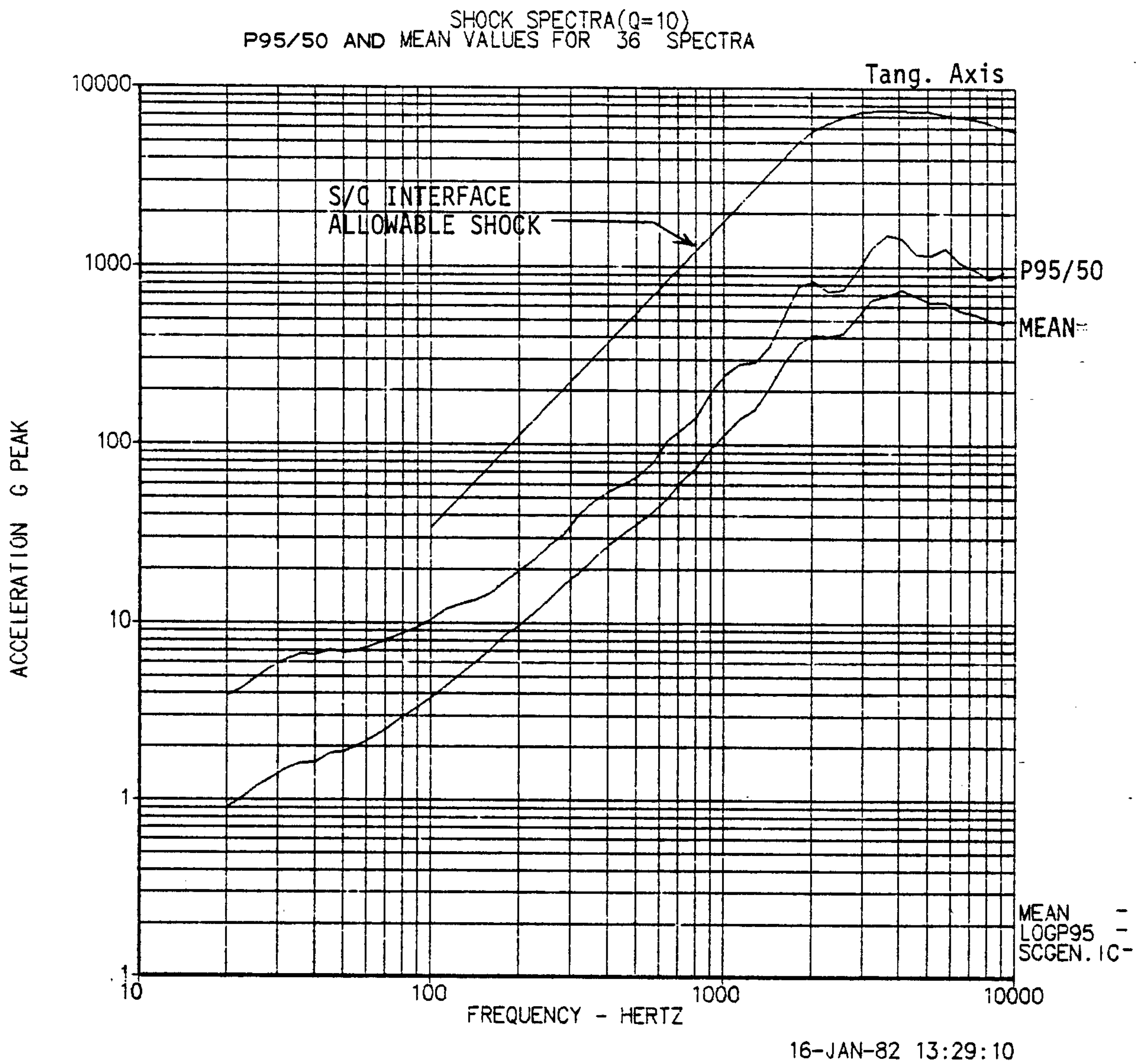


Figure 4.3-6

Comparison of S/C Interface Allowable Shock with I/II Staging Separation Shock Environment



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30	A					61	A				
31	A					62	A				

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		C-86	B	D-44	A			D-89	D		
		C-87	B	D-45	A			D-90	D		
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REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
A	This revision was released to include: (1) the analyses of S/C induced pyroshock environments; (2) ASE Super*Zip and Pin Puller Pyroshock environments; (3) a tabulation of component qualification methods (Table 3.3.2-A). IUS/SI Document Release Char Wickersham 82JUN29	6/21/82 6/25/82 6/28/82 6/28/82	F. W. Spann S. M. Church J. E. Honsberger E. A. Brown for J. J. Eckle
B	The purpose of this revision was to add Appendix C, Evaluation of IUS Equipment Compatibility with Spacecraft Generated Shock and Appendix A, Evaluation of IUS Equipment Compatibility with the TDRS Separation Environment IUS/SI Document Release 84JAN30 Char Wickersham (NTC/cw)	CB 1/19/84 1/12/84 1-31-84 BD	R. F. Hain S. M. Church J. E. Honsberger for J. J. Eckle
C	This revision adds Appendix E, Revised Shock Environment ASE/Orbiter. Revised environments defined by IRN 286 to ICD 2-19001. IUS/SI Document Release/DQA 88AUG05 Char Beckman	7/18/88 7/27/88 7/28/88 88-08-04 RFS DRR 8-12-88 8/1/88	C. J. Beck W. C. Gustafson P. H. Stern J. E. Honsberger for H. A. DiPamio

6-30-82 BD

DO 6000 2150 ORIG. 4/71

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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL
D	Rewrote Abstract. Added Volume 3 contents. Revised section 3 and 4 to include information on TITAN 4. Revised sections 3, 4 and 5 to include additional references. Added section 6, Flight Data. Revised Appendix D to include qualification test information for the REM, RF Switch and Fail Safe Relay.		C.J. Beck 3/26/93 H.L. Nordwall 3/26/93 A.D. Watson 3/26/93 J.H. Keeney 3/26/93
	IUS Document Release/DQA/02APR93/G. E. Parker	930405	RELEASED BY: D. Stevenson

Attachment to
2-3612-IUS-625

Evaluation of
IUS Equipment Compatibility
with the TDRS
Separation Shock Environment

Date 1 July 82
Revision A, 6 October 1982 | A

Prepared by
C.J. Beck

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A

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1.0 INTRODUCTION

Purpose

The purpose of this evaluation is to determine the compatibility of IUS equipment with the pyrotechnic shock environment induced by firing the devices used to separate TDRS from IUS Stage 2. An evaluation is also presented relative to the compatibility of IUS equipment with pyrotechnic shock environments created by firing devices used to deploy TDRS antennas and solar arrays.

Background

IUS Stage 2 equipment was designed and qualified for pyroshock environments based on measured shock data from the IUS Dynamic Test Vehicle (DTV) Stage 1/2 separation test conducted in 1978, Reference 1. The IUS equipment design environment is shown on Figure 1.0. The IUS equipment environment is an envelope of all shock spectra measured at equipment attach points on the DTV. Reference 2 discusses the derivation of the IUS equipment environment.

The spacecraft induced shock allowable on the IUS 379 ring as shown on Figure 1.0 is the envelope of shock spectra measured 3.5 inches from the IUS DTV separation nut. The spacecraft induced shock allowable was established from the 1978 IUS DTV shock data.

The induced shock environment envelope derived from data measured on the IUS Qualification Test Vehicle (QTV) spacecraft interface ring is also shown on Figure 1.0. The IUS QTV environment was measured on the IUS QTV 379 ring, Reference 3. There was no load on the IUS QTV ring during the separation shock test. No separation tests have been conducted with an IUS/Spacecraft configuration to measure the response of IUS equipment to spacecraft induced shock.

Scope

This document contains an evaluation of IUS equipment compatibility with TDRS induced shock. Section 2 presents a list of IUS equipment annotated to indicate equipment which must function after the spacecraft separation shock event. Section 3 discusses the analysis method used to predict the IUS equipment response to TDRS induced shock and contains shock spectra comparing the predicted TDRS induced shock with the IUS equipment capability. Section 4 presents conclusions and recommendations.

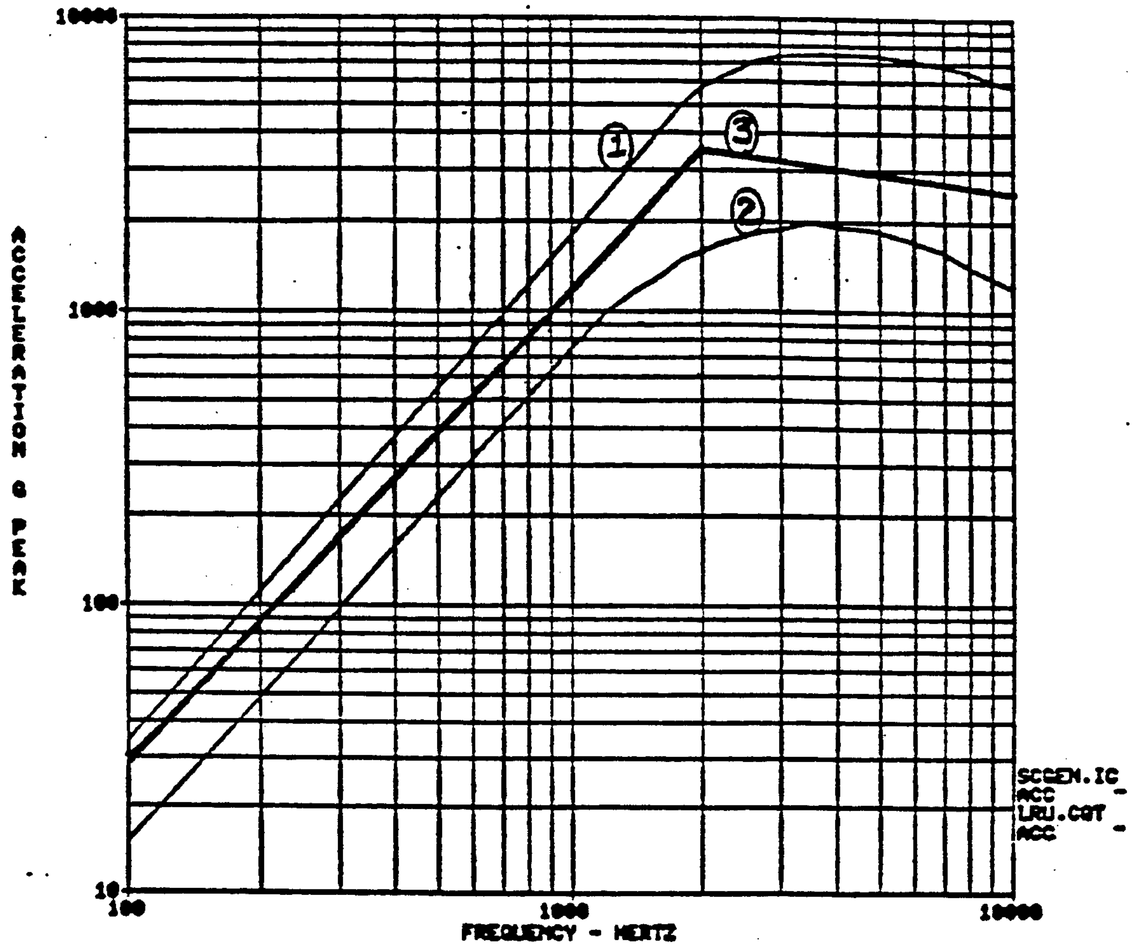


FIGURE 1.0

COMPARISON

1 Spacecraft Induced Shock Allowable

2 IUS Equipment Design Requirement

3 IUS Induced Shock Envelope at IUS 379 Ring, Measured on QTV

2.0 IUS EQUIPMENT LIST/FUNCTION

Figure 2.0 lists IUS equipment which was evaluated for compatibility with TDRS induced shock. Figure 2.0 also indicates the IUS equipment which is required to function after the TDRS separation shock event. TDRS/IUS will be launched from the Space Shuttle. (STS). The analyses are discussed in Section 3. A

FIGURE 2.0

IUS/TDRS EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO TDRS SEP	REQD AFTER TDRS SEP	
SRM-1	290-21000	X	X	X		
Safe & Arm	290-21005/C1290014A	X	X	X		
SRM-2	290-21001/C1290012A	X	X	X		
Safe & Arm	290-21005/C1290014A	X	X	X		
REM	290-21002/C1290020A	X	X		X	X
Manifold	290-21024	X	X		X	X
Tank Module Assy	290-21007	X	X		X	X
Resistor Board Assy	290-21066/C1290A30A	X	X		X	X
Star Scanner	290-22127/C1290039A	--	X	X		
Inertial Meas. Unit	290-22118/C1290024A	X	X		X	X
TVC Actuator	290-22116/C1290015A	X	X	X		
TVC Controller	290-22116/C1290015A	X	X	X		
TVC Potentiometer	290-22116/C1290015A	X	X	X		
Computer, Central Avion.	290-22119/C1290025A	X	X		X	X
Signal Cond. Unit (SCU)	290-26016/C1290016A	X	X		X	X
Code Plug, SCU	290-26100/	X	X		X	X
Signal Interface Unit (SIU)	290-26199/C1290199A	X	X		X	X
Titan Interface Unit (TIU)	290-26197/C1290197A	X	--	Not Applicable		
RF Switch (2 pole)	280-41008	X	X		X	X

FIGURE 2.0

IUS/TDRS EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO TDRS SEP	REQD AFTER TDRS SEP	
Antenna, Omni, DOD	290-27105	--	X		X	X
Antenna, Med. Gain (NASA)	290-27106	X	X	X		
SGLS Transponder, S Band	290-22121/C1290018A	X	X		X	X
20 Watt Amplifier, S Band	290-22117/C1290021A	X	X		X	X
Diplexer (DOD)	290-22200	X	X		X	X
Environ. Meas. Subsystem	290-22224	X	X		X	X
EMU Transducers	290-22228	X	X		X	X
Fail Safe R/F Relay	280-41009	X	--	Not Applicable		
DC Block	280-61001	X	--	Not Applicable		
Avionics Battery (140 AH) (Stage 1)	290-22211/C1290023A -1	X	X	X		
Utility Battery (13 AH)	290-22212/C1290037A	X	X		X	X
Avionics/Spacecraft Battery (100 AH) (Stage 1)	290-22211/C1290037A -2	--	X	X		
Avionics Battery (170 AH)	290-22211 -3	X	X	X		
T34D/IUS Destruct Battery	290-27001	X	--	Not Applicable		
DC/DC Converter Regulator	290-22210/C1290038A	[1]	[1]	[1] Optional Not on TDRS		
Pyro Switching Unit (PSU)	290-26054/C1290054A	X	X	X		
Power Transfer Unit (PTU)	290-27200/C1290056A	--	X	X		

FIGURE 2.0

IUS/TDRS EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO TDRS SEP	REQD AFTER TDRS SEP	
Power Distributor Unit (PDU)	290-26117/C1290017A	X	X		X	X
Isolation Diode Assy	290-26070	--	X	X		
Temperature Sensor Assy	290-26222	X	X	X		
Separation Nuts	290-24130/C1290019A	X	X	X		
Staging Mech. (Super Zip)	290-24006/C1290053A	X	--	Not Applicable		
T34D/IUS Destruct System	290-24172/C129093A	X	--	Not Applicable		
Safe and Arm	290-21005	X	--	X		
Extendable Exit Cone	290-21001/CI290012A	--	X	X		
Staging (Separation) Connector	290-27411	--	X	X		
Pyro Connector	290-27411	--	X	X		

3.0 SHOCK ANALYSIS

The IUS equipment reponse to TDRS induced separation shock was calculated using the following relationship.

$$S_C = TF \times S_S$$

S_C = Calculated shock spectrum at the IUS equipment location

S_S = Shock spectrum on the TDRS adapter when the separation device is fired

TF = Transfer function between the TDRS adapter and the IUS equipment location

The estimated TDRS adapter shock environment (S_S) is shown in Figure 3.0. This environment was measured during the TDRS adapter/separation band shock test conducted in 1979, Reference 4.

The transfer functions between the spacecraft adapter attach points and the IUS equipment locations were calculated using shock data from the IUS DTV/CS-3 separation shock test and the IUS QTV stage 1/2 separation shock test. The DTV/CS-3 test was conducted in January 1980, Reference 5. The IUS QTV test was conducted in May 1981, Reference 6. The transfer function calculations and calculation of the shock spectra at the IUS equipment locations were performed on a Digital Equipment Corporation, VAX 11/780 computer. The shock calculation programs were written by Fred Spann, Boeing Dynamics Staff.

The following subsections discuss the analysis details and results for the IUS equipment requiring analysis per Figure 2.0.

File Names HTDA.ENV.;1
HTDR.ENV.;1
HTDT.ENV.;1

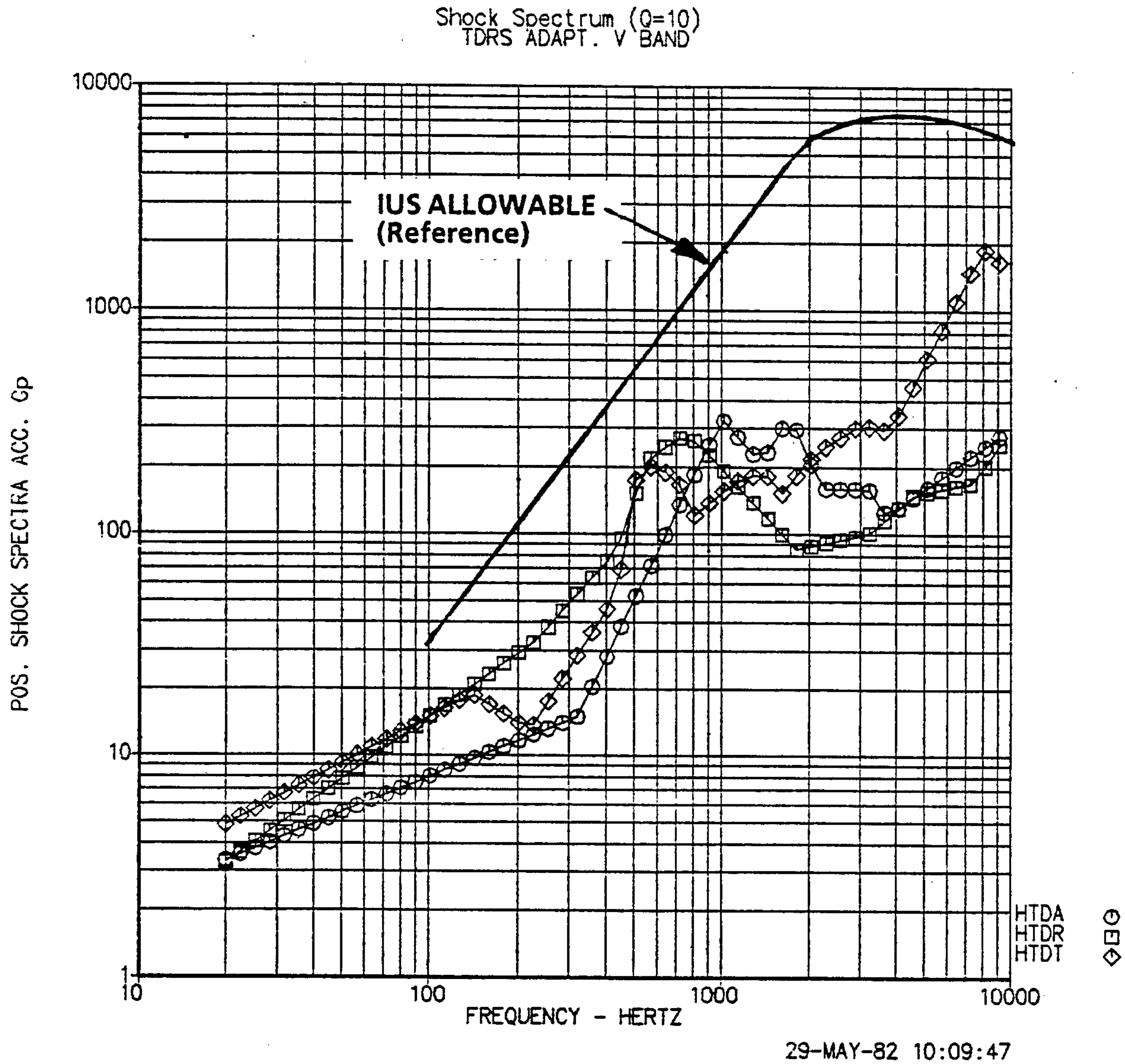


FIGURE 3.0

TDRS INDUCED SHOCK
DUE TO V BAND SEPARATION
AT IUS/TDRS INTERFACE, TDRS SIDE (S_S)
○ Axial □ Radial ◇ Tangential

3.1 IUS Equipment Analyzed

Figure 2.0 indicates IUS equipment requiring a shock analysis to evaluate compatiblity with TDRS induced shock. Previous analyses of DSCS and DSP induced shock, References 7 and 8, have shown that most of the IUS equipment is compatible with DSP and DSCS. Figures 3.1.1 thru 3.1.3 compare TDRS, DSCS and DSP induced separation shocks. Note that the TDRS shock is generally less than or equal to DSP and DSCS shock. Therefore, IUS equipment response to TDRS shock will be calculated for IUS equipment unique to the TDRS/Space Shuttle configuration or for IUS equipment which is not compatible with DSCS and/or DSP shock. IUS equipment fitting the above categories are:

(1) REM (not compatible with DSP shock)
(2) RF Switch (not compatible with DSP shock)
(3) Omni antenna (unique to TDRS/Space Shuttle)

3.2 REM (Rocket Module) Shock Prediction

The equations and data used to predict the REM response to TDRS induced shock are similar to those described in the DSP and DSCS analyses, References 7 and 8. The predicted environments are shown in Figure 3.2.

3.3 RF Switch Shock Prediction

The subject switch is not compatible with the DSP induced shock at frequencies above 4000 Hz, Réference 8. The shock comparisons shown on Figures 3.1.1 thru 3.1.3 of this document show that the TDRS shock is very much lower than the DSP shock at frequencies above 4000 Hz. Therefore, the subject switche is obviously compatible with the TDRS induced shock.

3.4 Omni Antenna Shock Prediction

The equations and data used to predict the omni antenna response to the spacecraft induced shock are shown on Figure 3.4.1. The omni antennas are mounted on the IUS stage 2 longerons as shown in Figure 3.4.2. the predicted omni antenna response to the TDRS induced separation shock is shown in Figure 3.4.3.

3.5 TDRS Appendage Shock

Appendix a contains an evaluation of IUS equipment compatibility with the shock produced by activation of TDRS appendage release devices.

A

File Names HDSPSA.;4
HDSCBA.;5
HTDA.ENV.;2

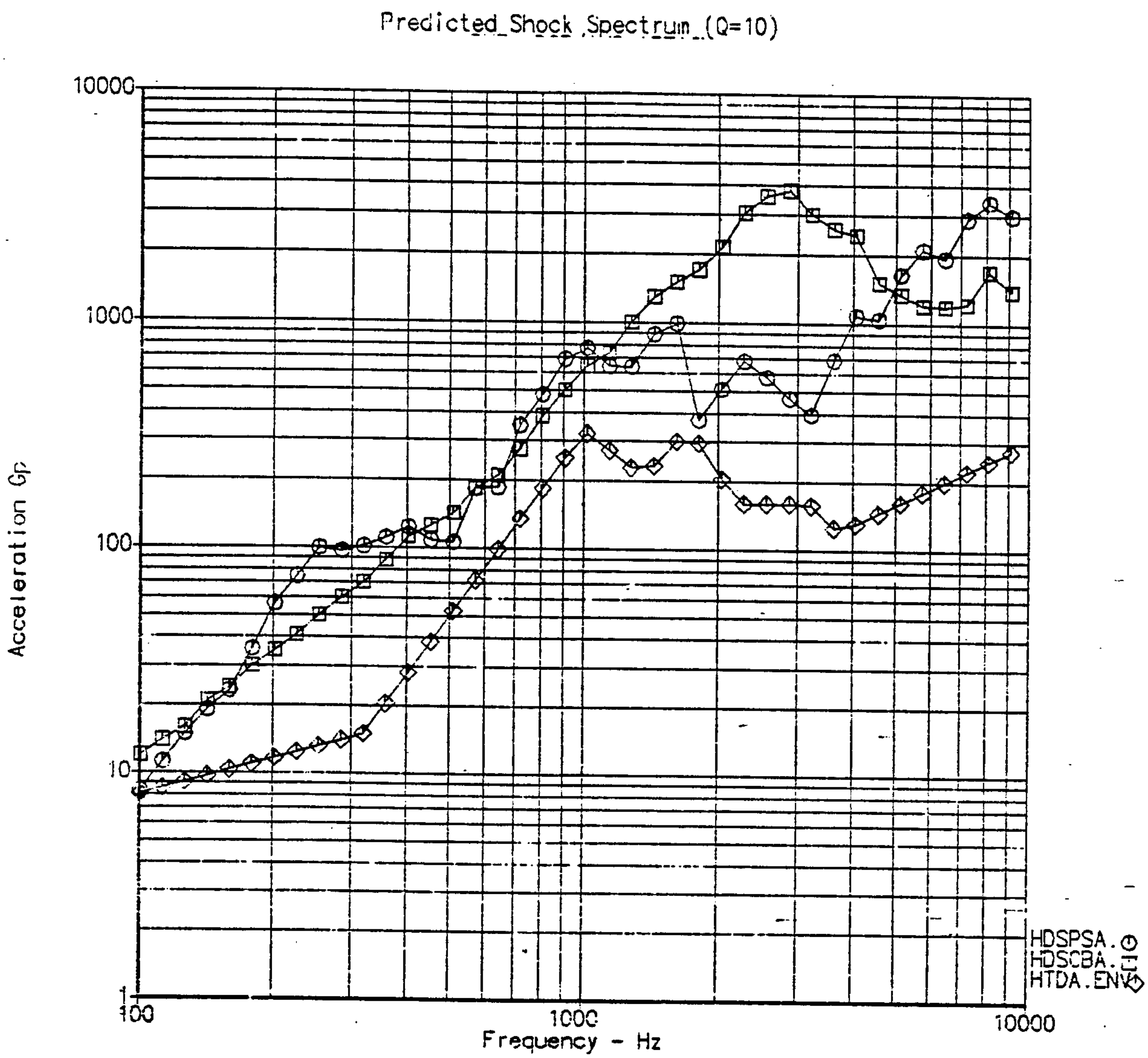


FIGURE 3.1.1
COMPARISON OF TDRS, DSCS AND DSP
INDUCED SEPARATION SHOCKS
AT IUS SPACECRAFT INTERFACE
Axial

◇ **TDRS** ○ **DSP** □ **DSCS**

File Names HDSPSR.;4
HDSCBR.;4
HTDR.ENV.;2

Predicted Shock Spectrum (Q=10)

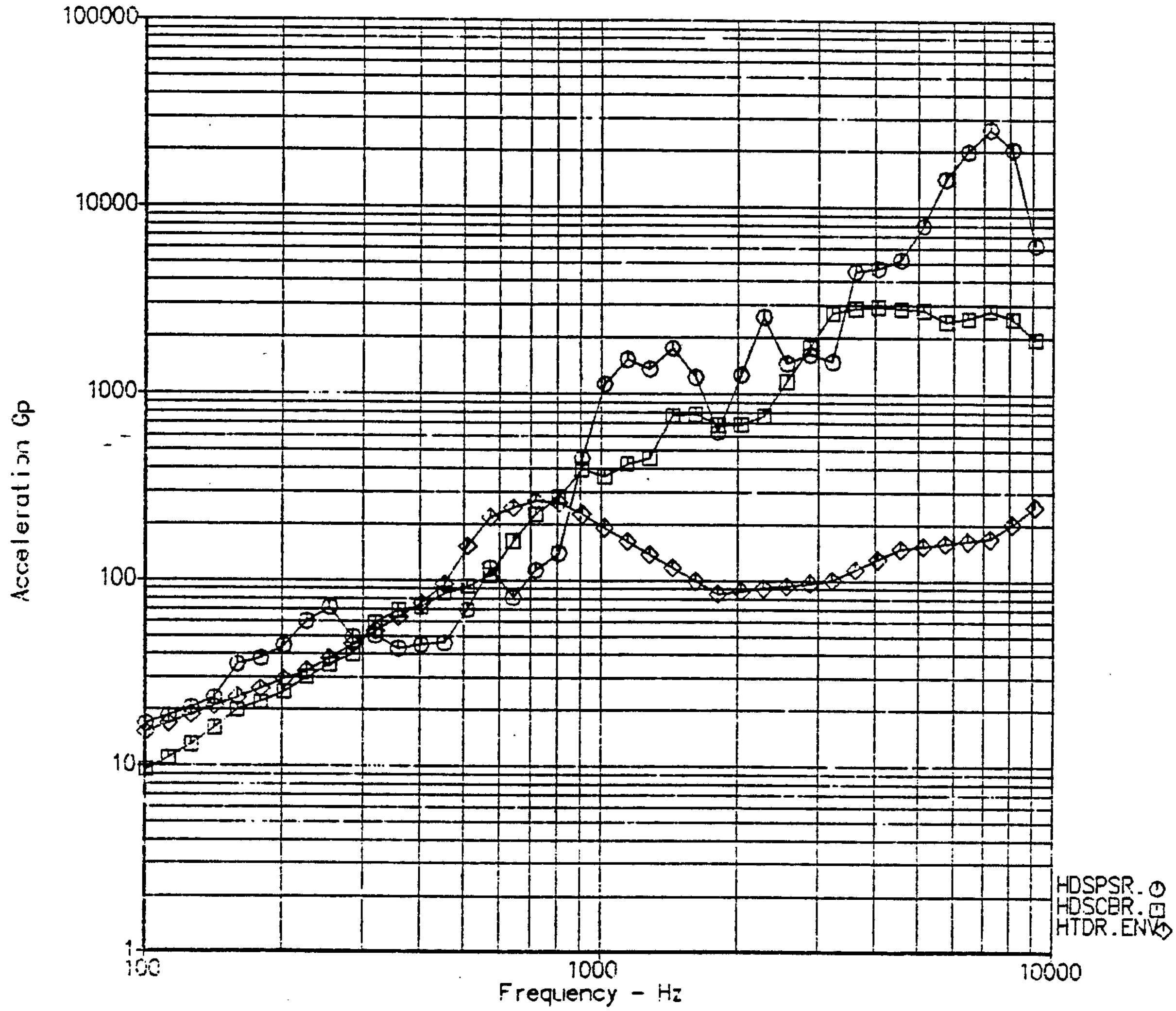


FIGURE 3.1.2

COMPARISON OF TDRS, DSCS AND DSP
INDUCED SEPARATION SHOCKS
AT IUS SPACECRAFT INTERFACE
Radial

◇TDRS ○ DSP □DSCS

File Names HDSPST.;5
HDSCBT.;3
HTDT.ENV.;2

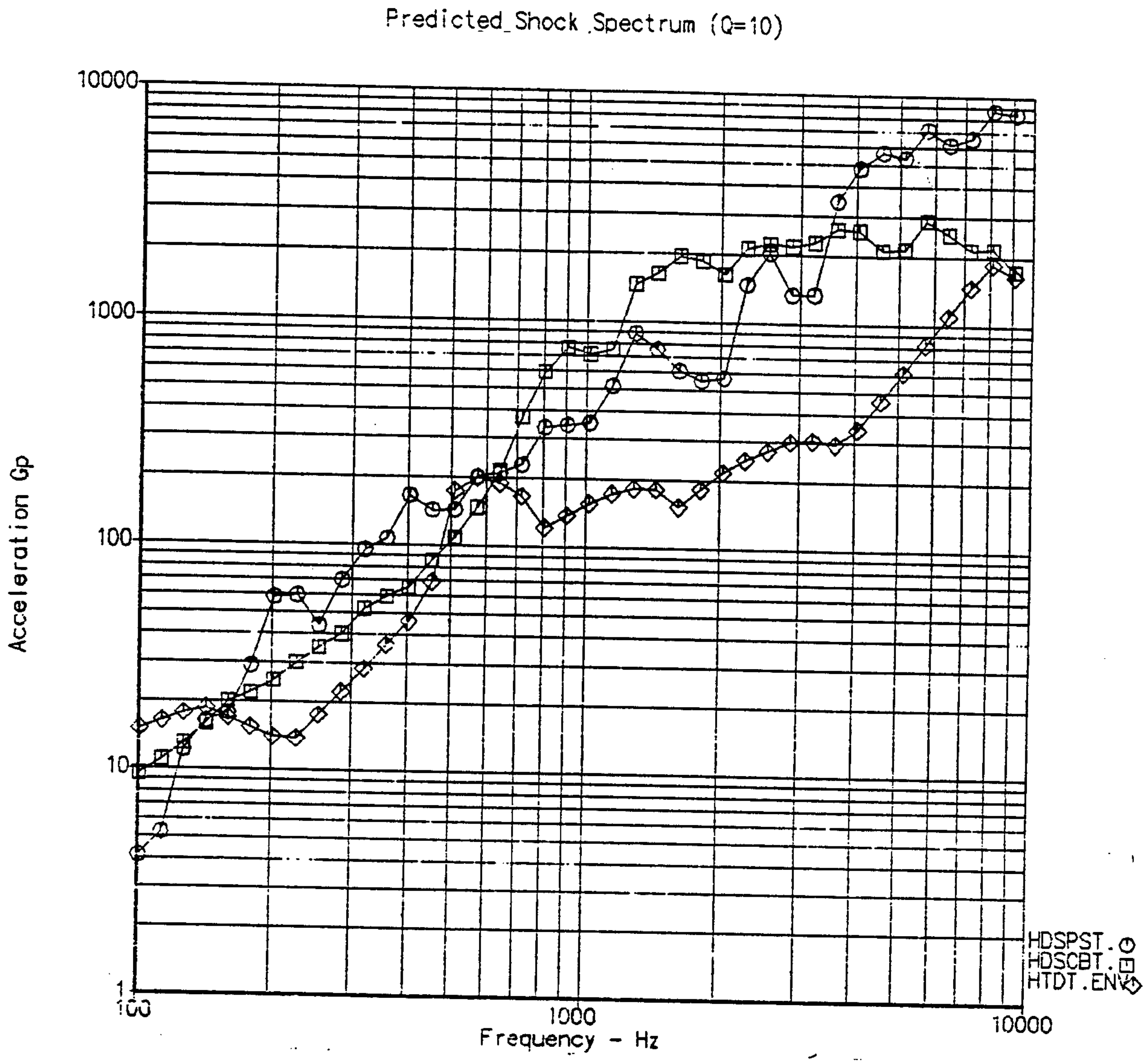


FIGURE 3.1.3

COMPARISON OF TDRS, DSCS AND DSP
INDUCED SEPARATION SHOCKS
AT IUS/SPACECRAFT INTERFACE
Tangential
◇TDRS ○DSP □DSCS

TDSN19R.;1 = HTDR.ENV.;1 (AN19RDSP.DB;4)

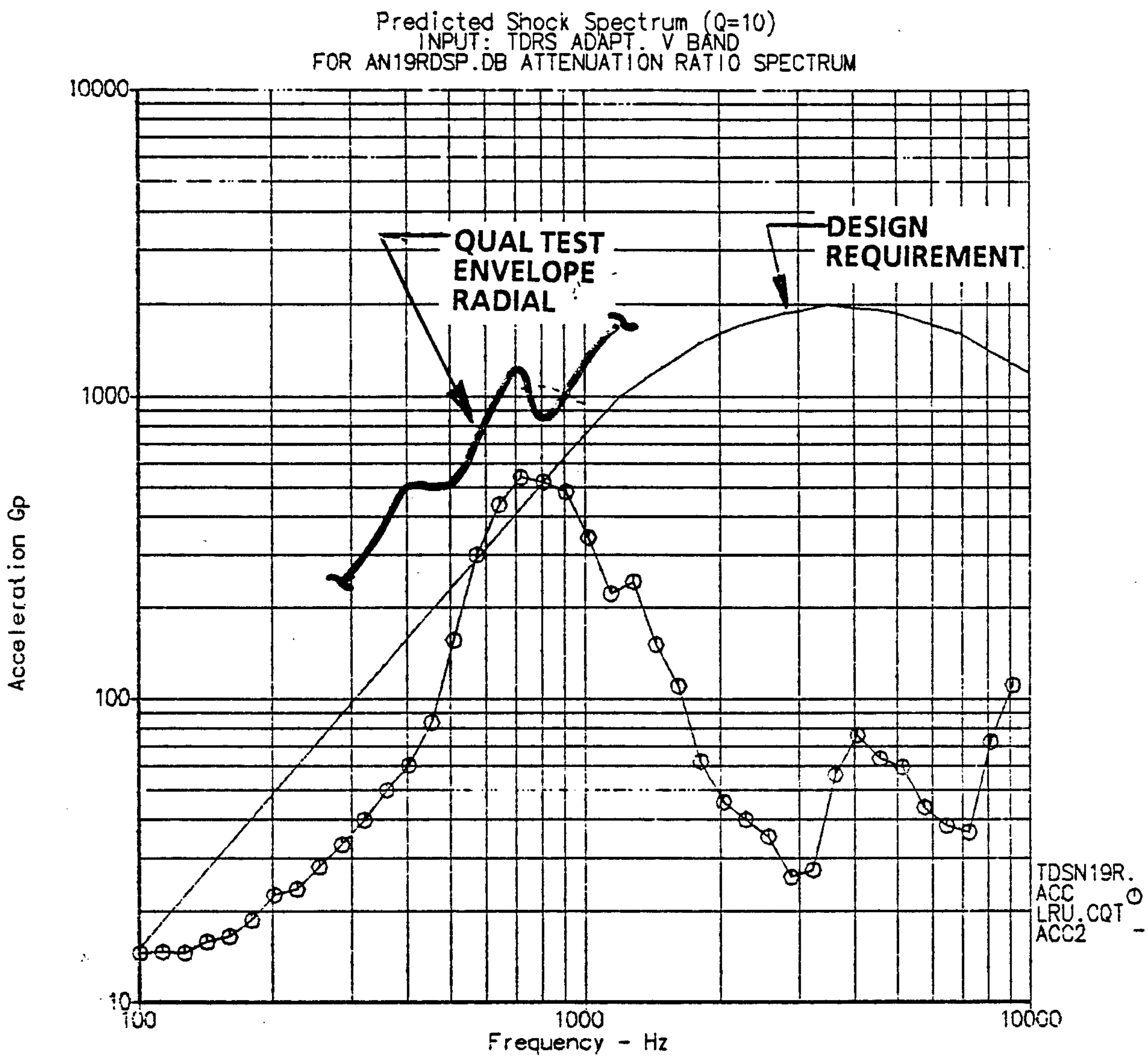


FIGURE 3.2.1

TDRS INDUCED SHOCK
AT IUS REM LOCATION, N19
O **Radial**

TDSN19T.;1 = HTDT.ENV.;1 (AN19TDSP.DB;3)

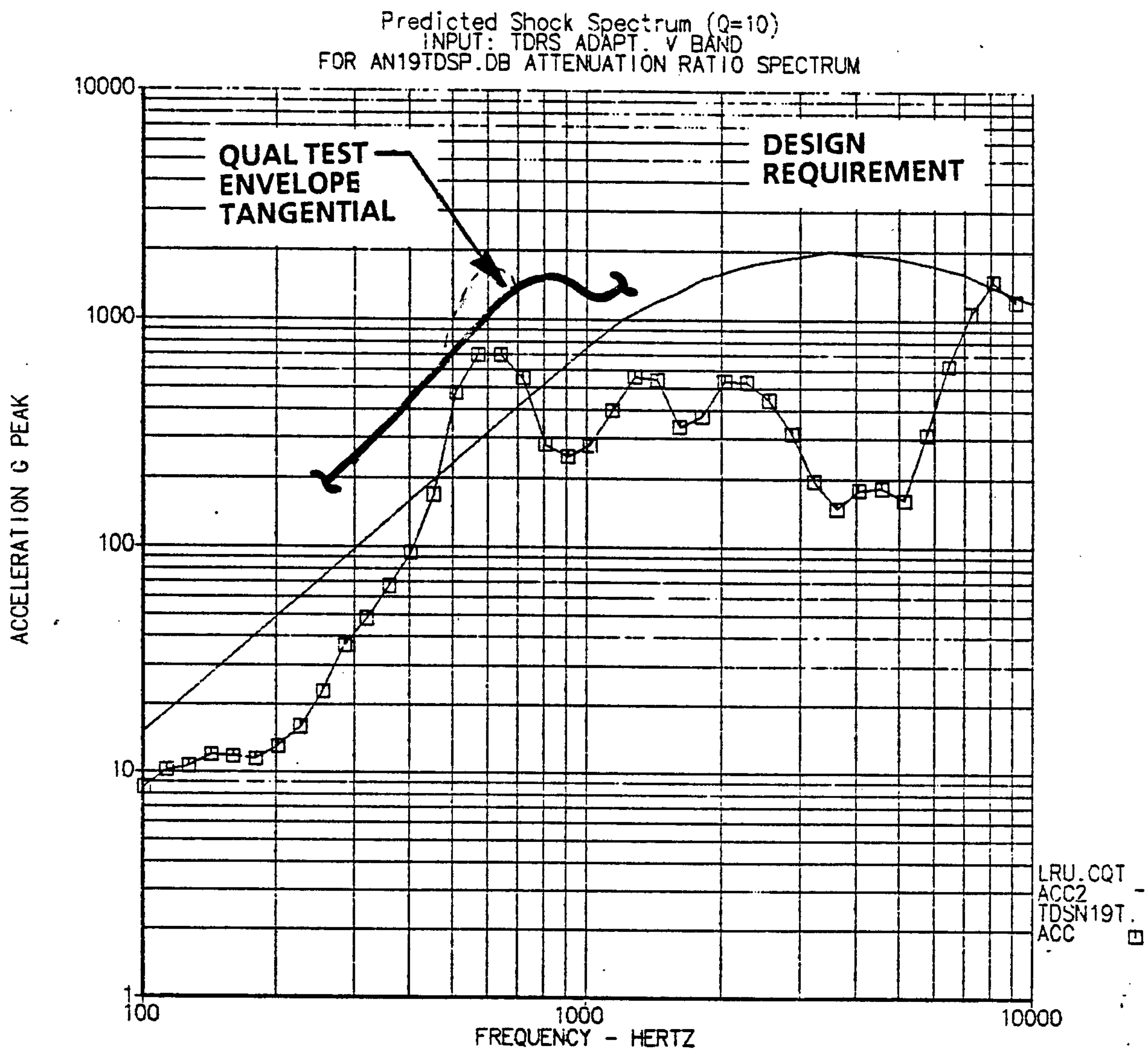


FIGURE 3.2.2

TDRS INDUCED SHOCK
AT IUS REM LOCATION, N19
☐ **Tangential**

BOEING

NUMBER
REV LTR

GENERAL EQUATION SEE FIGURE 3.4.2

$$S_c = S_s\left(10^{\frac{-A1}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface). See Figure 1.
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

B = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies

APPLICABLE ACCELEROMETERS/EQUATIONS

A1, the attenuation across the spacecraft IUS joint was calculated using data from the IUS/CS-3 separation test conducted in 1980. and discussed in Boeing memo 2-3964-0000-029 dated 22 Feb 80. The attenuation values of A1 are shown in Reference 8, Figure 3.1.3.

FINAL EQUATIONS

$$S_{N_{13}} = S_{N_{12}} = S_{N_{25}} = S_{N_{42}} = S_{N_{56}} = S_s\left(10^{-\frac{A1}{20}}\right)$$ See Figure 3.4.3.

FIGURE 3.4.1

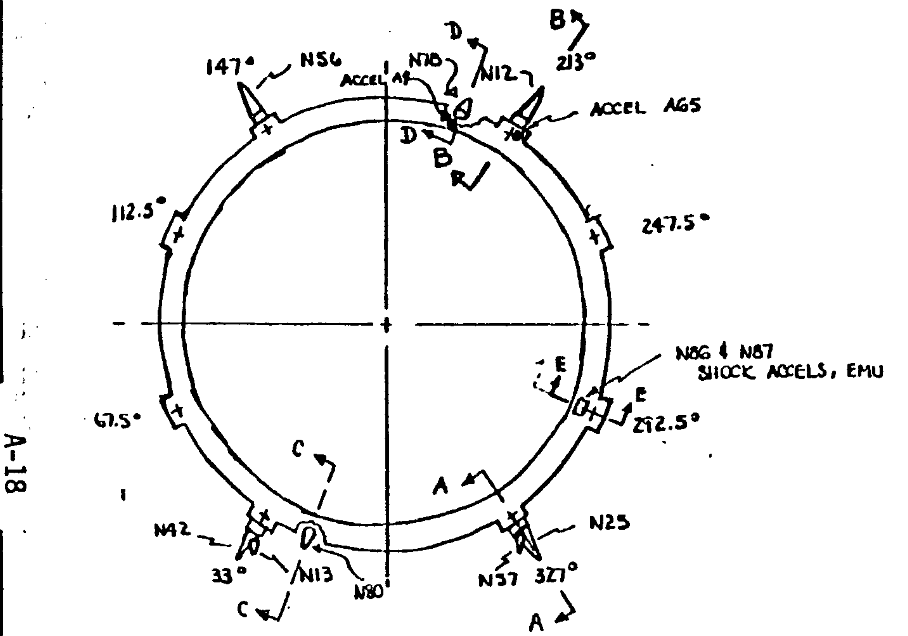
SHOCK EQUATIONS

CB 7/2/82

SHEET

BOEING

NUMBER
REV LTR



COMPONENT		LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH NUMBER OF JOINTS	
					S_I ~ IUS			S_D ~ S/C				
ID.	NAME	X_C	Θ_C	R_C	X_I	Θ_I	R_I	X_D	Θ_D	R_D	I-C	S-C
N12	OMNI ANTENNA	370"	213°	60"	359"	213°	51	379"	213°	55"	17/1	
N13	MED. GAIN ANT.	375	33	60	↓	33	↓	↓	33	↓	21/1	
N25	OMNI ANT.	370	327	60°	↓	327	↓	↓	327	↓	17/1	
N42	OMNI ANT.	370	33°	60	↓	33	↓	↓	33	↓	17/1	
N56	OMNI ANT.	370	147°	60	↓	147	↓	↓	147	↓	17/1	
N57	MED. GAIN ANT.	375	327	60	↓	327	↓	↓	327	↓	21/1	
N78	MED. GAIN ANT.	375	200	50	↓	213	↓	↓	213	↓	37/1	16/1
N80	MED. GAIN ANT.	369	20	50	↓	33°	↓	↓	33	↓	42/1	22/1
N86	SHOCK ACCEL.	379	292.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1
N87	SHOCK ACCEL.	379	292.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1

STS: N12–N57; T34D: N78–N80

I-C = Shock path length from IUS Separation Nut to Component

S-C = Shock path length from Spacecraft Attach point to Component

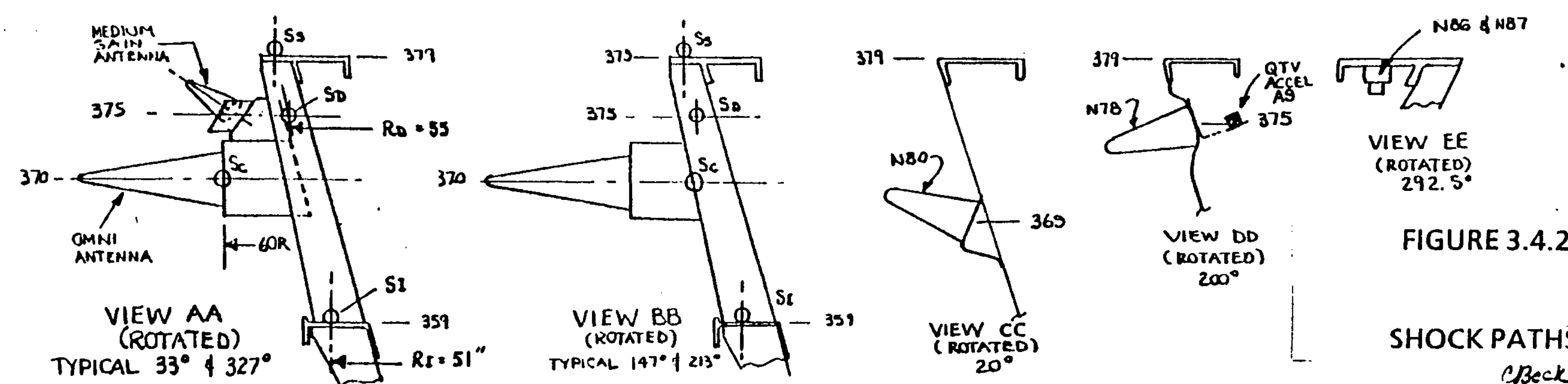


FIGURE 3.4.2

SHOCK PATHS

CBeck 4/28/82

TDSN13.;1 = HTD*.;1 (C3LC3S*.DB;1)*
** = A, R or T*

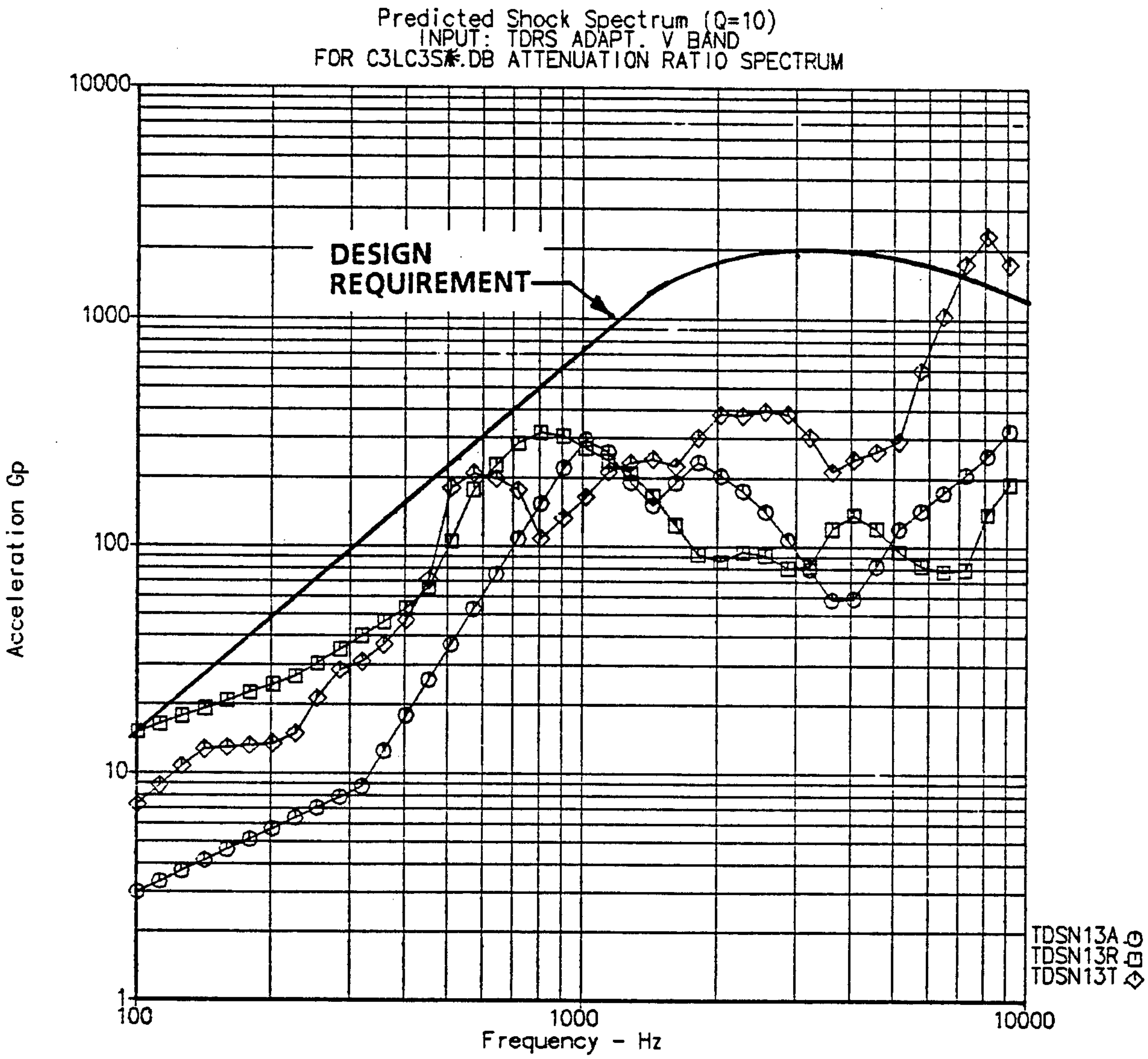


FIGURE 3.4.3

TDRS INDUCED SHOCK
AT IUS OMNI ANTENNA LOCATIONS
○ **Axial** □ **Radial** ◇ **Tangential**

4.0 CONCLUSIONS / RECOMMENDATIONS

All IUS components are compatible with TDRS induced shock. Rationale for this conclusion follows.

1. TDRS induced shock due to V band separation is generally less than or equal to DSCS and DSP induced shock, Figures 3.1.1 thru 3.1.3. Most of the IUS equipment is compatible with DSCS and DSP induced shock.

2. The REM is considered to be compatible with TDRS induced shock even though predicted levels exceed the REM design requirement, Figures 3.2.1 and 3.2.2. The rationale for this conclusion follows.

   a) Qualification test levels are greater than predicted levels.
   b) The REM is mounted on vibration isolators.

3. The Omni Antenna is considered to be compatible with TDRS induced shock even though predicted levels exceed the omni antenna design requirement, Figure 3.4.3 The antenna is a simple device with no moving parts and pyro shock tests for antennas are optional per MIL-STD-1540A, Table II.

4. IUS equipment is compatible with TDRS induced shock due to appendage device activation, see Appendix A. A

REFERENCES

1. TIS No. 11-2-002-1, IUS Separation Test - Pyrotechnic Shock, Boeing Aerospace Co. Final Test Report (T + 45 Day CDRL 077A2), dated 20 February 1978.

2. D290-10080-1, Subsystem Design Analysis Report. Environmental Vibration, Revision D, 27 February 1978.

3. Final Report Special Study FSD-81-003, "IUS Pyrotechnic Shock Reduction, Stage I/II Separation", 10 July 1981.

4. TRW letter 79-8241.5-107; to G.D. Fooks from E.A. Pugh; subject, TDRSS Adapter/Separation Band Test; 3 April 1979.

5. LMSC/D715175; CS-3/IUS Pyrotechnic Shock Measurement Data, IUS Stage 1/2 Separation Tests, December 1979 - January 1980; 1 Feb 1980. Lockheed Missiles and Space Co. inc; Sunnyvale, CA.

6 Test Report No. 22B5-005R-1, Pyro Shock-Staging/Separation QTV,Volumes 1 and 2, Boeing Aerospace Co.; 1 December 1981.

7. Memo 2-3612-IUS-590; to S. M. Church from C.J. Beck; subject Compatibility Analysis-IUS Components with DSCS Induced Shock; 29 April 1982:Boeing Aerospace Co.; Seattle, WA.

8. Memo 2-3612-IUS-614; to S.M. Church from C. J. Beck;subject, Compatibility Analysis - IUS Components with DSP 12,13 Induced Shock; 28 May 1982; Boeing Aerospace Co.; Seattle, WA.

9. Memo 2-3612-IUS-618; to T. Hansen et. al. from S. M. Church; subject,IUS Component Re-Qualification for Spacecraft Induced Shock 1 June 1982; Boeing Aerospace Co. Seattle ; WA.

APPENDIX A

APPENDAGE SHOCK ANALYSIS

CONFIGURATION DESCRIPTION

Prior to separation of IUS from TDRS the following TDRS appendages are deployed by the devices indicated.

Solar Arrays, 24 bolt cutters
SGL Antenna, 2 pin - pullers
C Band Antenna, 1 pin - puller

These appendages are shown in figure A-1. The locations of the appendage release devices relative to the IUS/TDRS interface are shown in figure A - 2.

SHOCK ANALYSIS

The shock environment due to activation of the appendage release devices was estimated using the Martin Marietta Pyrotechnic Shock Design Guidelines Manual [1]. The estimated shock environment at the IUS/TDRS interface (IUS station 379) was calculated using the following relationship.

$$S_I = TF \times S_A$$

S_I = calculated shock spectrum at IUS/TDRS interface

TF = transfer function between appendage release device and IUS/TDRS interface

S_A = shock spectrum at appendage release device location

1. MCR 69-611, Aerospace Systems Pyrotechnic Shock Data, Volume VI; Martin Marietta Corp.; Denver, CO; March 1970.

The shock spectra (S_A) for pin - pullers and boltcutters are shown in figure A - 3. These spectra are from MCR-69-611.

The transfer function (*TF*) between the pyrotchnic devices and the IUS/TDRS interface is estimated to be an attenuation factor of 0.04 (28 db). This factor was obtained from MCR-69-611 for equipment mounting structure and a distance from the source of 100 inches. The 100 inch distance isthe shock path length shown in figure A - 2.

The estimated shock spectrum at the IUS/TDRS interface is shown in figure A - 4. The environment was calculated by multiplying the pin - puller spectrum of figure A - 3 by the attenuation factor 0.04. The shock environments due to TDRS V band separation are shown on figure A - 4 for reference.

CONCLUSION

The appendage device shock is less than or very close to the shock environments produced by V band separation, see figure A - 4. Therefore, the IUS equipment is compatible with appendage device shock based on the rationale presented in section 4 of this report.

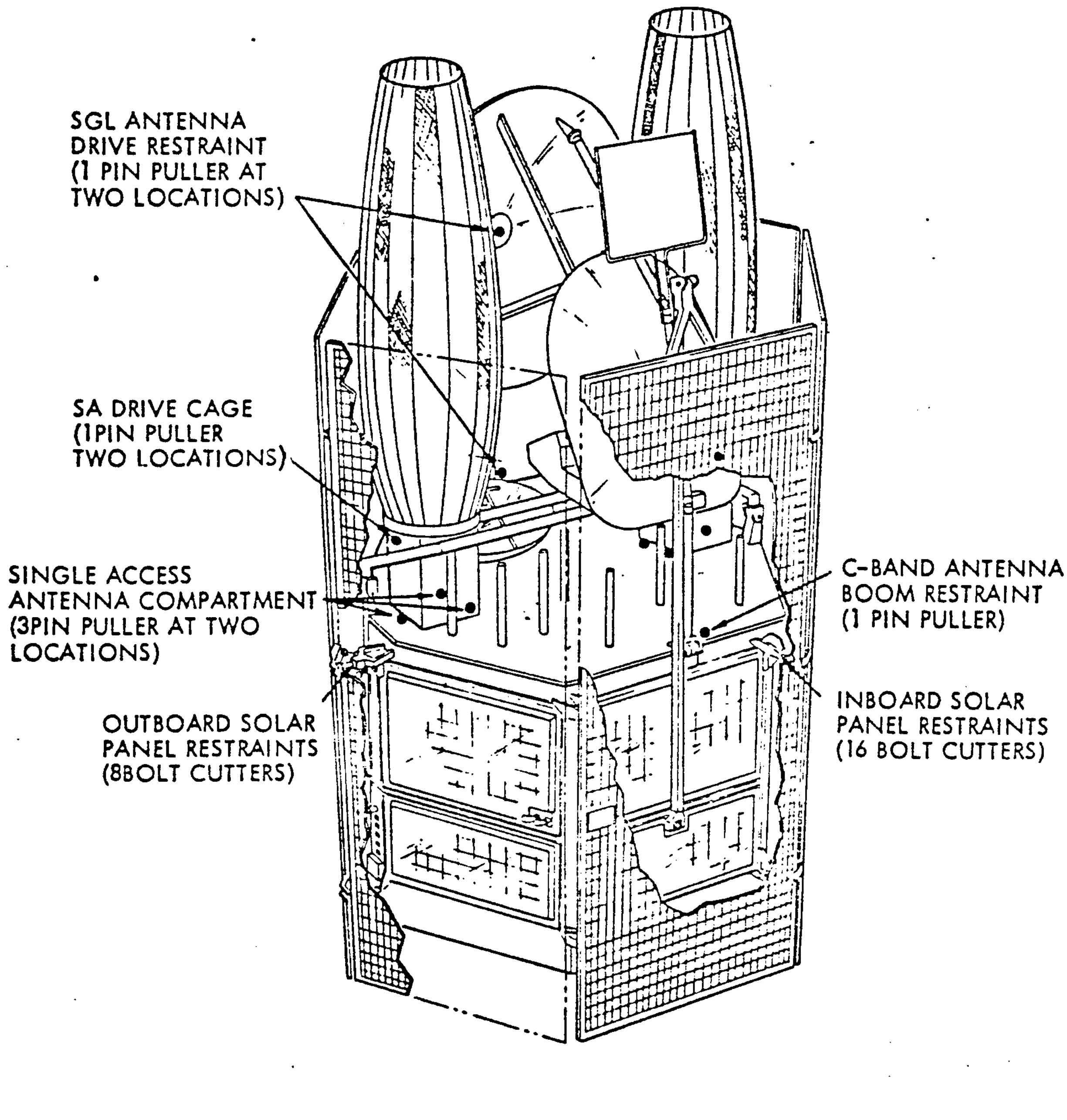


FIGURE A-1
TDRS APPENDAGE RELEASE DEVICES

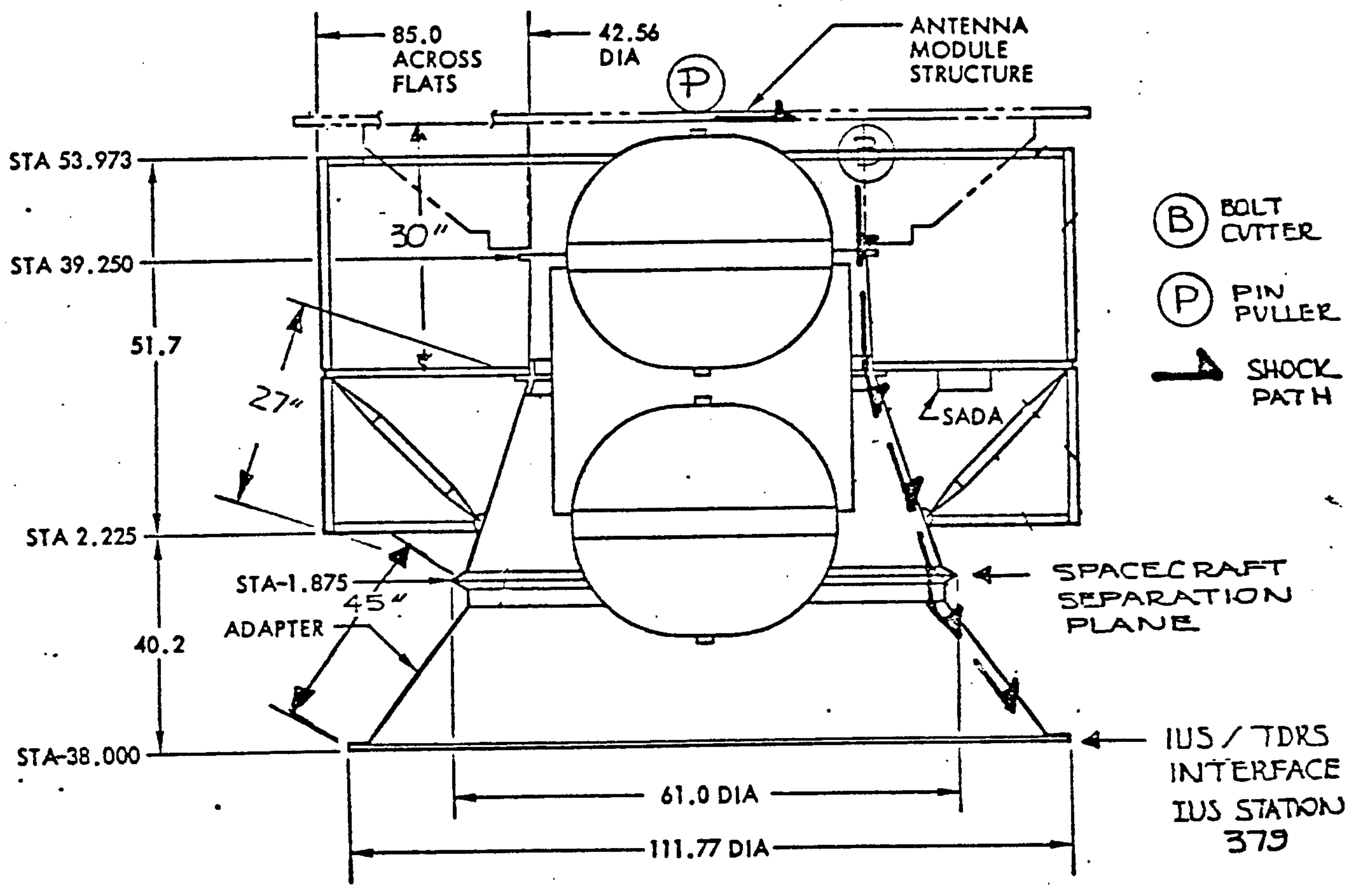


FIGURE A-2
SHOCK PATH

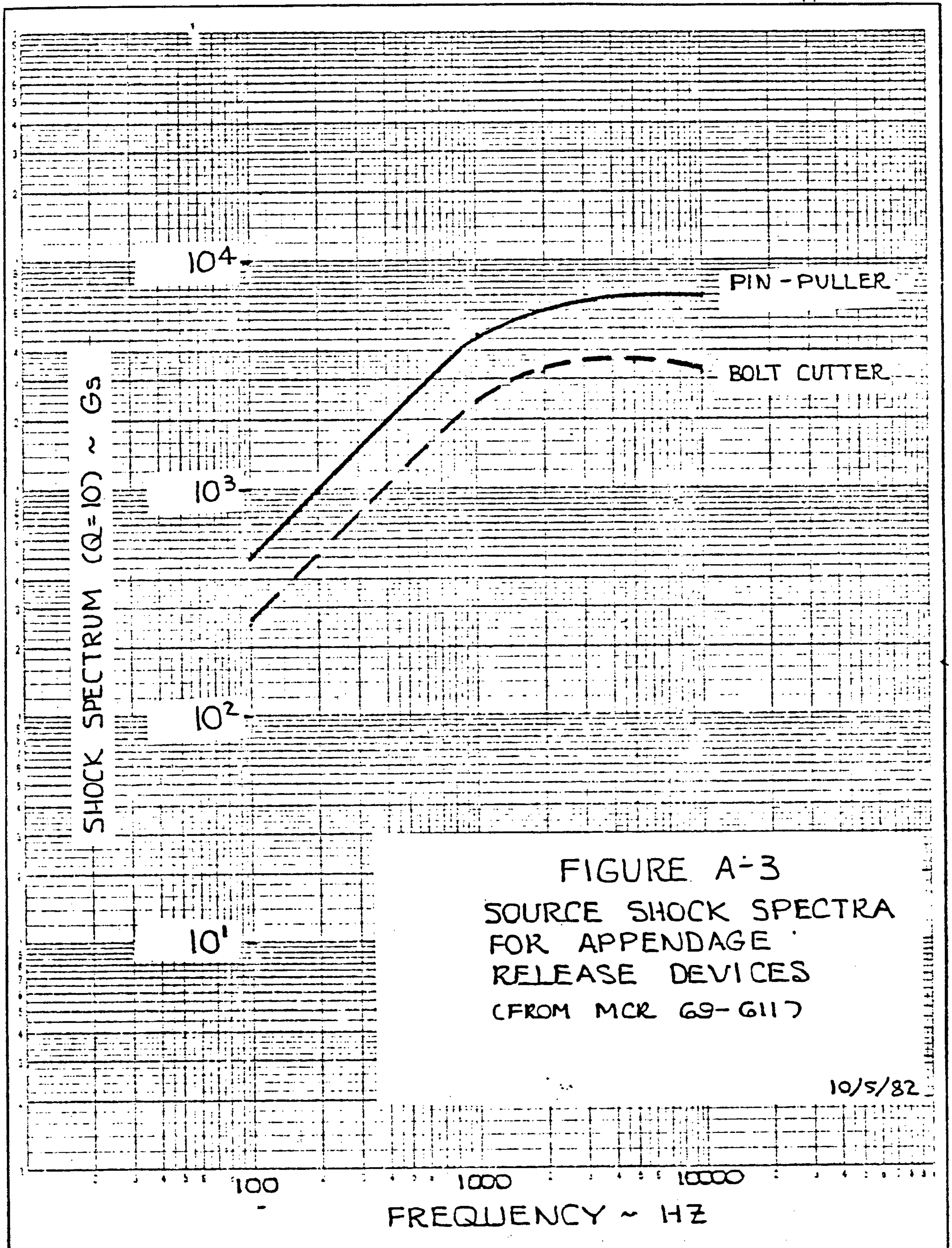


FIGURE A-3
SOURCE SHOCK SPECTRA
FOR APPENDAGE
RELEASE DEVICES
(FROM MCR 69-611)

O, □, ◇ TDRS SEPARATION BAND
SHOCK AT IUS/TDRS INTERFACE
(REFERENCE)

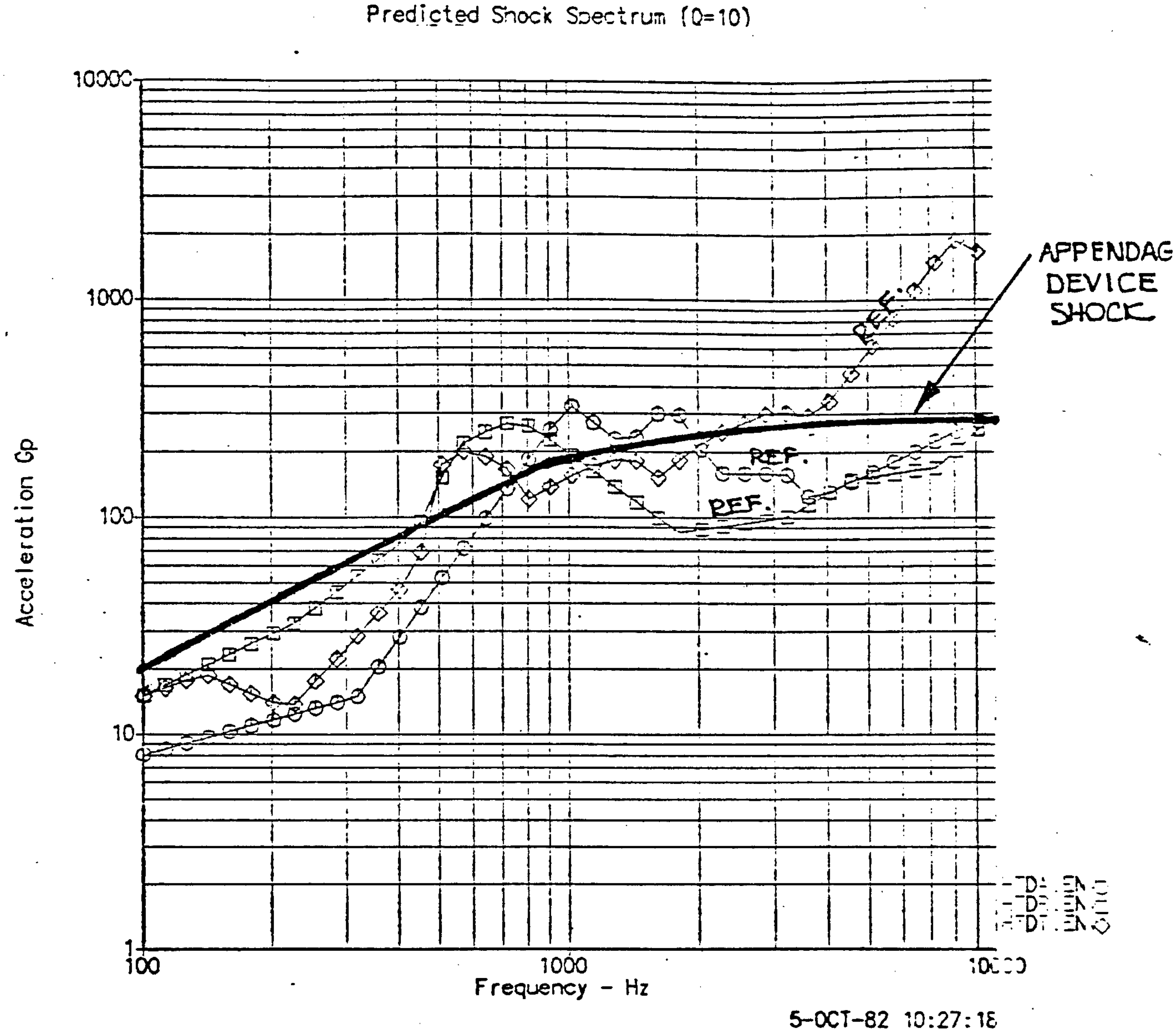


FIGURE A-4
TDRS INDUCED SHOCK
DUE TO APPENDAGE DEVICES
AT IUS/TDRS INTERFACE, TDRS SIDE

APPENDIX B

Evaluation of
IUS Equipment Compatibility
with the DSCS II/III Induced
Separation Shock Environment

Date 29 April 82

Prepared by
C. J. Beck

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1.0 INTRODUCTION

Purpose

The purpose of this evaluation is to determine the compatibility of IUS equipment with the pyrotechnic shock environment induced by firing the devices used to separate DSCS II/III from IUS Stage 2.

Background

IUS Stage 2 equipment was designed and qualified for pyroshock environments based on measured shock data from the IUS DTV Stage 1/2 separation test conducted in 1978, Reference 1. The spacecraft induced shock allowable was established from the same IUS DTV shock data. The IUS equipment design environment is shown on Figure 1.0. The IUS equipment environment is an envelope of all shock spectra measured at equipment attach points on the DTV. Reference 2 discusses the derivation of the IUS equipment environment. The spacecraft induced shock allowable on the IUS 379 ring as shown on Figure 1.0 is the envelope of shock spectra measured 3.5 inches from the IUS DTV separation nut. The induced shock environment envelope derived from data measured on the IUS QTV spacecraft interface ring is also shown on Figure 1.0. The IUS QTV environment was measured on the IUS QTV 379 ring, Reference 3. There was no load on the IUS QTV ring during the separation shock test. No separation tests have been conducted with an IUS/Spacecraft configuration to measure the response of IUS equipment to spacecraft induced shock.

Scope

This document contains an evaluation of IUS equipment compatibility with DSCS II/III spacecraft induced separation shock. Section 2 presents a list of IUS equipment annotated to indicate equipment which must function after the spacecraft separation shock event. Section 3 discusses the analysis method used to predict the IUS equipment response to DSCS induced shock and contains shock spectra comparing the predicted DSCS induced shock with the IUS equipment capability. Section 4 presents conclusions.

2.0 IUS EQUIPMENT LIST/FUNCTION

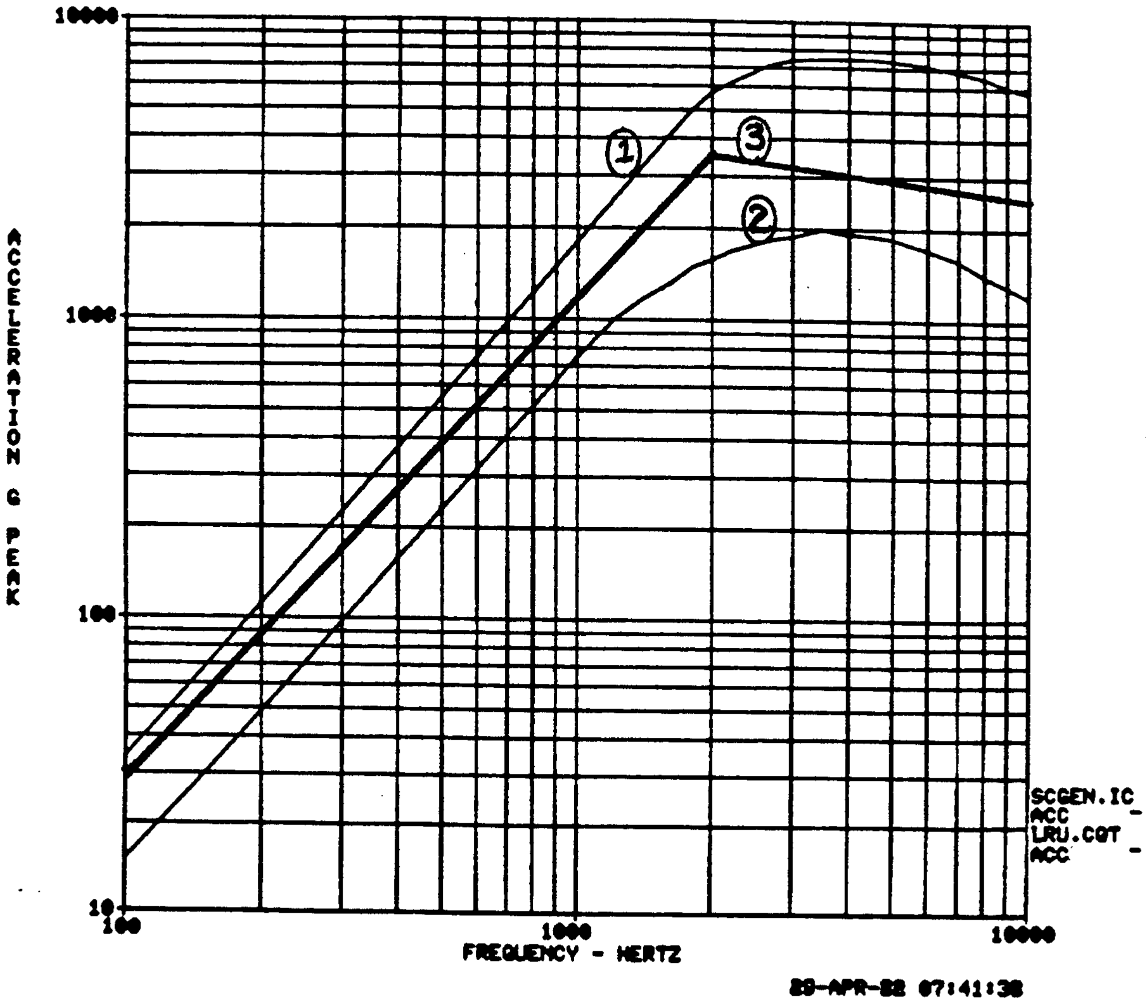
Table 2.0 lists IUS equipment which was evaluated for compatibility with DSCS II/III induced separation shock. Table 2.0 also indicates the IUS equipment which is required to function after the DSCS separation shock event. DSCS II/III/IUS will be launched from a T34D launch vehicle. Shock compatibility analyses were performed for IUS equipment (T34D configuration) which is required to function after the DSCS separation shock event. The analyses are discussed in Section 3.0.

Reference 1 TIS No. 11-2-002-1, IUS Separation Test - Pyrotechnic Shock, Boeing Aerospace Co. Final Test Report (T+45 Day CDRL 077A2), dated 20 February 1978.

Reference 2 D290-10080-1, Subsystem Design Analysis Report, Environmental Vibration, Rev. D, 27 February 1978.

Reference 3 Final Report Special Study FSD-81-003, "IUS Pyrotechnic Shock Reduction, Stage I/II Separation", 10 July 1981.

THE BOEING COMPANY



COMPARISON

1. Spacecraft Induced Shock Allowable
2. IUS Equipment Design Requirement
3. IUS Induced Shock Envelope at IUS 379 Ring, Measured on QTV

FIGURE 1.0

TABLE 2.0

IUS/DSCS EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO DSCS SEP	REQD AFTER DSCS SEP	
SRM-1	290-21000	X	X	X		
Safe & Arm	290-21005/C1290014A	X	X	X		
SRM-2	290-21001/C1290012A	X	X	X		
Safe & Arm	290-21005/C1290014A	X	X	X		
REM	290-21002/C1290020A	X	X		X	X
Manifold	290-21031	X	X		X	X
Tank Module Assy	290-21007	X	X		X	X
Resistor Board Assy	290-21066/C1290A30A	X	X		X	X
Star Scanner	290-22127/C1290039A	--	X		Not Applicable	
Inertial Meas. Unit	290-22118/C1290024A	X	X		X	X
TVC Actuator	290-22116/C1290015A	X	X	X		
TVC Controller	290-22116/C1290015A	X	X	X		
TVC Potentiometer	290-22116/C1290015A	X	X	X		
Computer, Central Avion.	290-22119/C1290025A	X	X		X	X
Signal Cond. Unit (SCU)	290-26016/C1290016A	X	X		X	X
Code Plug, SCU	290-26100/	X	X		X	X
Signal Interface Unit (SIU)	290-26199/C1290199A	X	X		X	X
Titan Interface Unit (TIU)	290-26197/C1290197A	X	X	X		
RF Switch (2 pole)	280-41008	X	X		X	X

TABLE 2.0

IUS/DSCS EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO DSCS SEP	REQD AFTER DSCS SEP	
Antenna, Omni, DOD	290-27105	--	X	Not Applicable		
Antenna, Med. Gain (NASA)	290-27106	X	X		X	X
SGLS Transponder, S Band	290-22121/C1290018A	X	X		X	X
20 Watt Amplifier, S Band	290-22117/C1290021A	X	X		X	X
Diplexer (DOD)	290-22200	X	X		X	X
Environ. Meas. Subsystem	290-22224	X	X		X	X
EMU Transducers	290-22228	X	X		X	X
Fail Safe R/F Relay	280-41009	X	--		X	X
DC Block	280-61001	X	--	X		
Avionics Battery (140 AH) (Stage 1)	290-22211/C1290023A	X	X	X		
Utility Battery (13 AH)	290-22212/C1290037A	X	X		X	X
Avionics/Spacecraft Battery (100 AH) (Stage 1)	290-22211/C1290037A	--	X	X		
Avionics Battery (170 AH)	290-22211/	X	X	X		
T34D/IUS Destruct Battery	290-27001	X	--	X		
DC/DC Converter Regulator	290-22210/C1290038A	1	1			
Pyro Switching Unit (PSU)	290-26054/C1290054A	X	X	X		
Power Transfer Unit (PTU)	290-27200/C1290056A	--	X	Not Applicable		

1 Optional
Not on DSCS 2/3

TABLE 2.0

IUS/DSCS EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO DSCS SEP	REQD AFTER DSCS SEP	
Power Distributor Unit (PDU)	290-26117/C1290017A	X	X		X	X
Isolation Diode Assy	290-26070	--	X	Not Applicable		
Temperature Sensor Assy	290-26222	X	X	X		
Separation Nuts	290-24130/C1290019A	X	X	X		
Staging Mech. (Super Zip)	290-24006/C1290053A	X	--	X		
T34D/IUS Destruct System	290-24172/C129093A	X	--	X		
Safe and Arm	290-21005	X	--	X		

3.0 SHOCK ANALYSIS

Analysis Method

The IUS equipment response to DSCS induced separation shock was calculated using the following relationship.

Sc = TF X Ss

where: Sc = Calculated shock spectrum at the IUS equipment location

Ss = Shock spectrum measured on the DSCS Bipod Foot when the DSCS Separation Device is fired

TF = Transfer Function between the DSCS Bipod Foot and the IUS equipment location

The DSCS Bipod Foot shock environment (Ss) is shown in Figure 3.0. This environment was derived from data obtained during the DSCS III qualification satellite/AC-2 separation shock test, Reference 4.

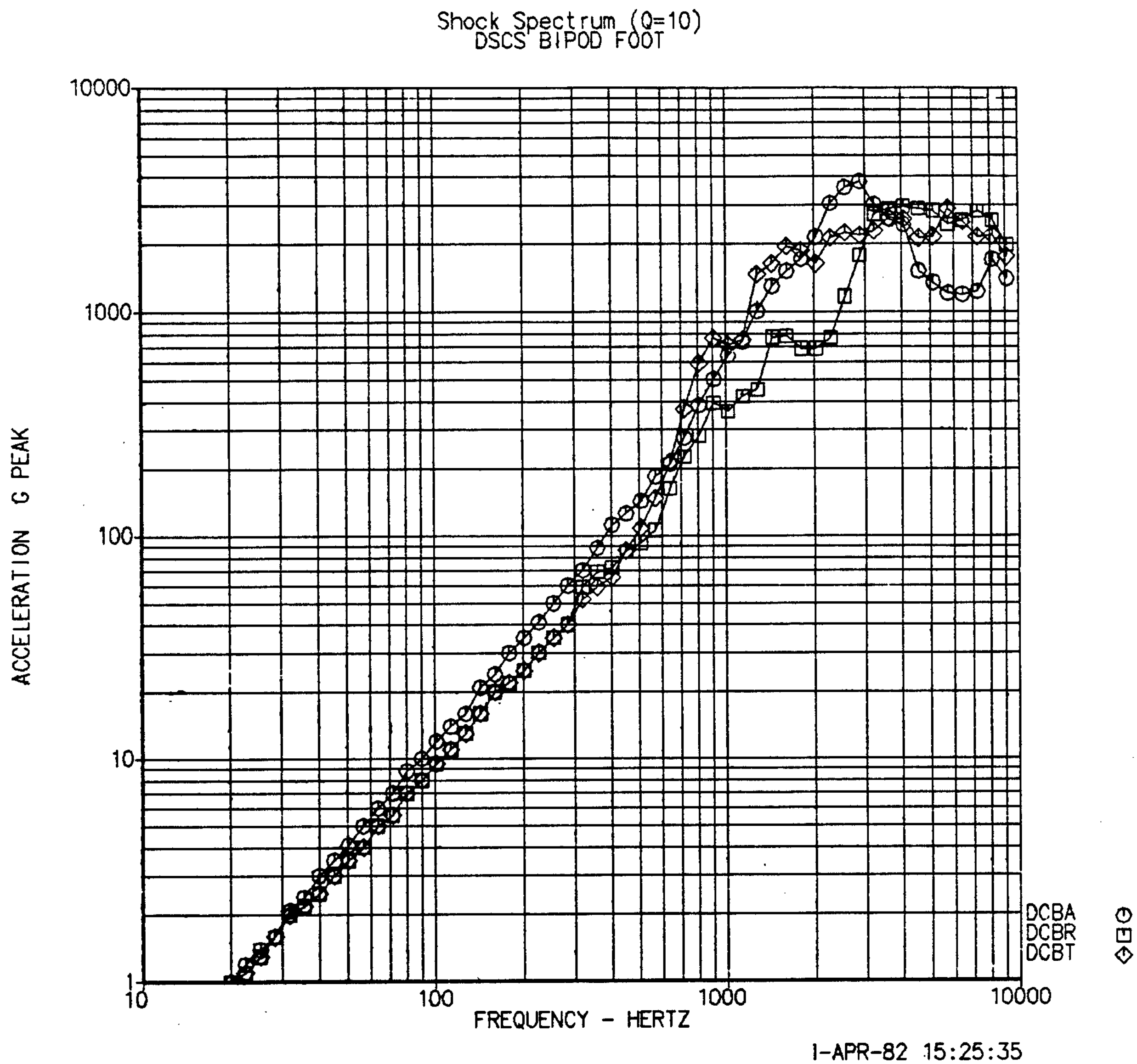
The Transfer Functions between the DSCS Bipod Foot and the IUS equipment locations were calculated using shock data from the IUS QTV Stage 1/2 separation shock test. The IUS QTV test was conducted during May 1981. The shock spectra from the test are documented in Reference 5.

The Transfer Function calculations and calculation of the shock spectra at the IUS equipment locations were performed on a Digital Equipment Corporation, VAX-11/780 computer. The shock calculation programs were written by Fred Spann, Boeing Dynamics Staff.

The following subsections, 3.1 through 3.8, discuss the analysis details and results for the IUS equipment requiring analysis per Table 2.0.

Reference 4 General Electric Letter CTR-6048; to Lt. L. Reagan from G. H. Hoke; subject, Transmittal of DSCS III Qual Satellite/AC-2 Separation Shock Data Contract F04701-77-C-0036, 5 April 1982.

Reference 5 Test Report No. 22B5-005R-1, Pyro Shock-Staging/Separation QTV, Volumes 1 and 2, Boeing Aerospace Co., 1 December 1981.



DSCS III INDUCED SHOCK
AT DSCS BIPOD FOOT

AXIAL
RADIAL
TANGENTIAL

(1981 DATA)

CALC	CB	1APR82	REVISED	DATE	FIGURE 3.0	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE B-9

3.1 REM* (Rocket Engine Module) Shock Prediction

The equations and data used to predict the REM response to DSCS induced shock are shown on Figure 3.1.1. The REMs are at 6 different locations on the IUS as shown on Figure 3.1.2. The predicted environments are shown in Figures 3.1.7, 3.1.8 and 3.1.9.

* BAC Drawing 290-21002/CI290020A

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NUMBER
REV LTR

GENERAL EQUATION

SEE FIGURE 3.1.2

$$S_C = S_S\left(10^{\frac{-A1 - A2 - AB}{20}}\right)$$

A1 = Attenuation across Spacecraft/IUS joint
A2 = Attenuation between Ss and Sc
AB = Attenuation correction for distance.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

B = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

Subscripts
d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies

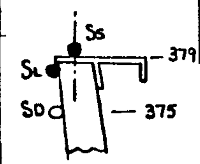
APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

A1A = 2.5 db A1R = 5db A1T = 5db

The above values based on IUS QTV and DSCS/Transtage Data as shown in Figures 3.1.3, 3.1.4, 3.1.5. The IUS QTV attenuations were calculated using the following equations.

$$A1 = 20 \log \frac{(\bar{S}_{Ld})_f}{(\bar{S}_{Sd})_f}$$

LONGERON θ	QTV ACCELS. S_L	QTV ACCELS. S_S
67.5°	25 ART	62 ART
112.5°	37 ART	63 ART
147	24 AR	64 ART
213	2 ART	65 ART
247.5	—	66 ART
292.5	—	67 ART
327	39 A	68 ART



Attenuation AB = -1.7

$$AB = 20 \log \frac{21.7 \text{ in.}}{26.6 \text{ in.}}$$

Attenuations A2A, A2R, A2T are shown in Figure 3.1.6. The attenuations were calculated using the following equations.

$$A2 = 20 \log \frac{(\bar{S}_{65d})_f}{(\bar{S}_{4d})_f}$$

shock path = 26.6 IN

QTV ACCELS. S_S	QTV ACCELS. S_C
θ = 213°	θ = 189°
65 ART	4 ART

FINAL EQUATIONS

$$S_{N51} = S_{N49} = S_{N19} = S_{N17} = S_S\left(10^{\frac{-A1-A2+1.7}{20}}\right) \Longrightarrow$$

$$S_{N2} = S_{N37} = S_S\left(10^{-\frac{A2-A1}{20}}\right)$$

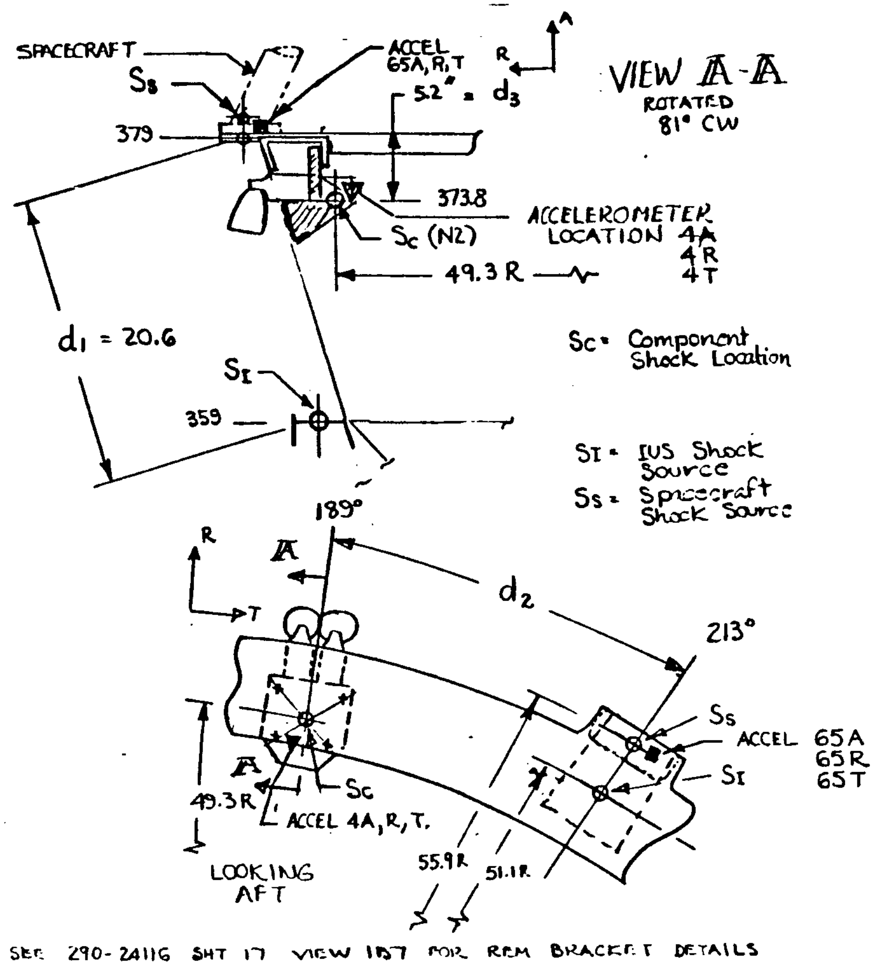
The predicted shock spectra are shown in Figures 3.1.7, 3.1.8, 3.1.9

FIGURE 3.1.1
REM
SHOCK EQUATIONS

CJB 4/22/82

THE BOEING COMPANY

NUMBER
REV LTR



REM ID	Sc REM LOCATION X_c (IN)	Θ_c	R_c (IN)	S_I IUS X_I	Θ_I	R_I	S_S S/C X_s	Θ_s	R_s	PATH LENGTH ▷ I-C	S-C
N2*	373.8	189°	49.3	359	213°	51.1	379	213°	55.9	47.2	26.6
N17		266°			247.5			247.5		42.3	21.7
N19		274°			292.5			292.5		42.3	21.7
N37		9°			33°			33°		47.2	26.6
N49		86°			67.5			67.5		42.3	21.7
N51		94°			112.5			112.5		42.3	21.7

(The "LOCATION NEAREST SOURCE" heading spans the S_I IUS and S_S S/C columns.)

▷ Shock path length calculations

I-C = Path length from IUS Separation Nut to REM

$$I\text{-}C \cong d_1 + d_2 + d_3 = 20.6 + \frac{|\Theta_c - \Theta_I|}{360}(2\pi R_I) + 5.2$$

$$I\text{-}C = 25.8 + 0.89|\Theta_c - \Theta_I|$$

S-C = Path length from Spacecraft Interface Attachment to REM

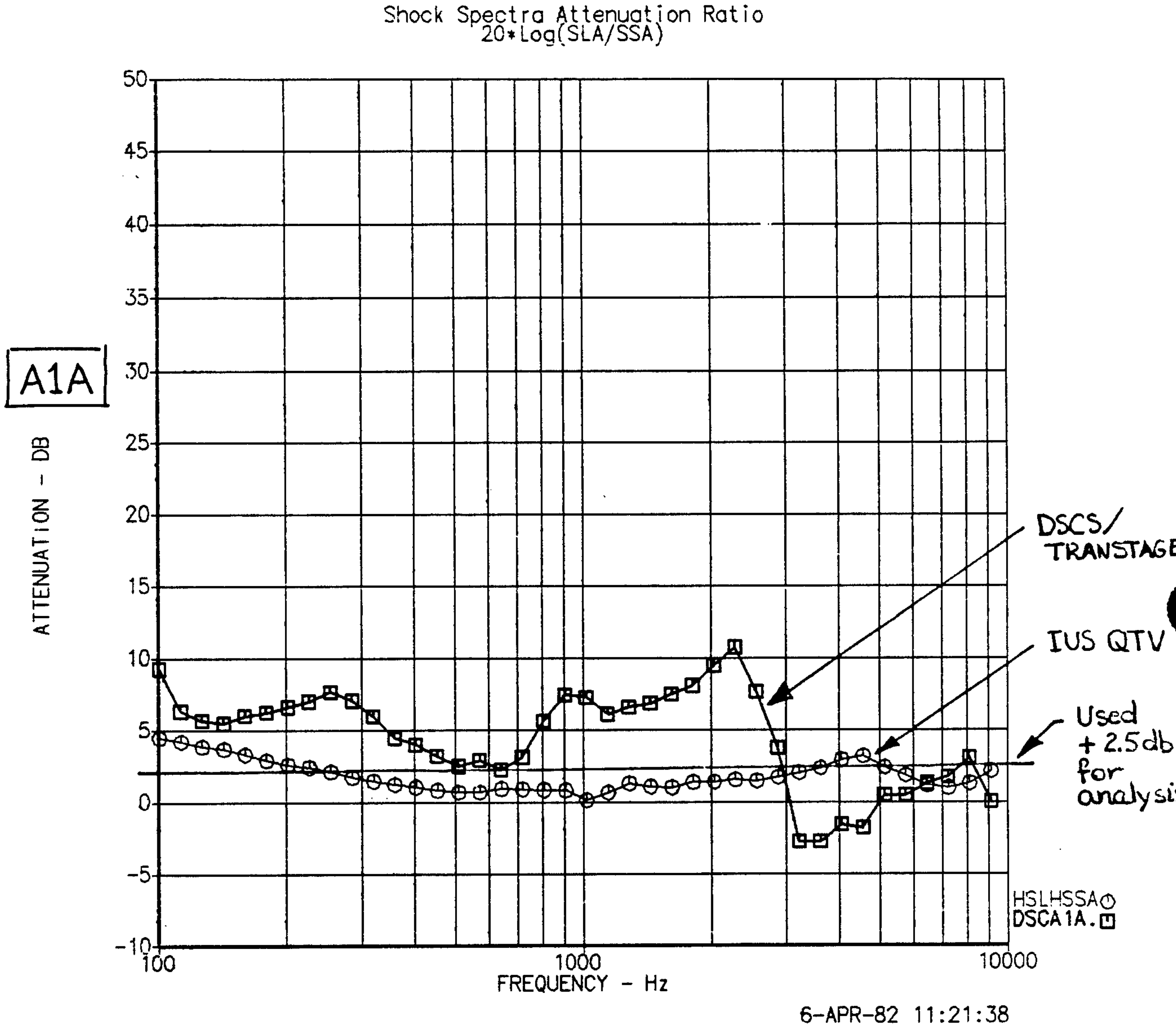
$$S\text{-}C \cong d_2 + d_3$$

* This REM instrumented during QTV pyro shock test, Accelerometers 4A, 4R, 4T.

FIGURE 3.1.2
REM SHOCK PATHS

C.J.Beck 4/29/82

O, □ } See notes on Figure 3.1.5



ATTENUATION ESTIMATES
SPACECRAFT TO LAUNCH VEHICLE JOINT

AXIAL

CALC	CB	6APR82	REVISED	DATE	FIGURE 3.1.3	
CHECK						
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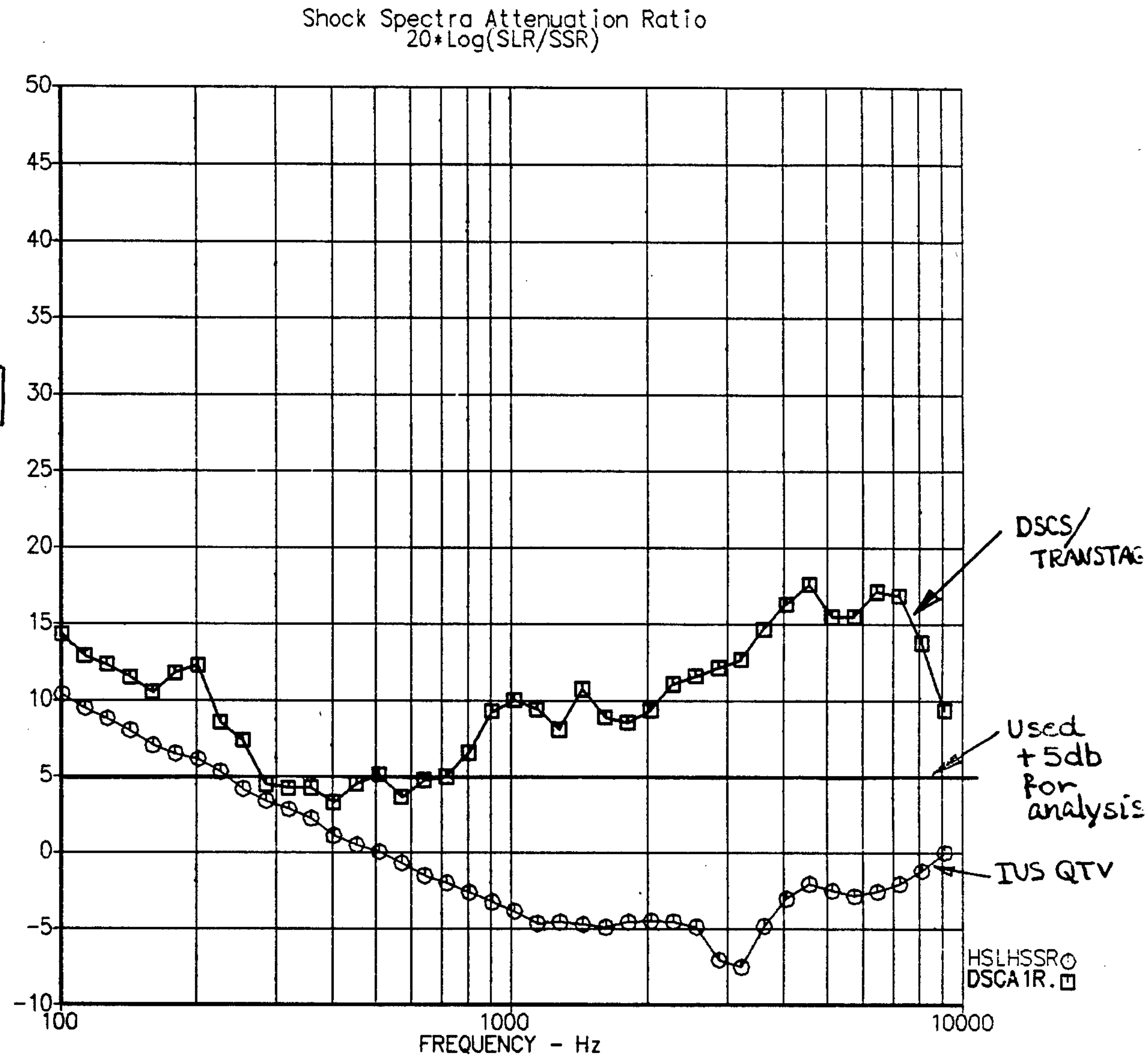
○ □ } See notes on Figure 3.1.5

A1R



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ATTENUATION ESTIMATES
SPACECRAFT TO LAUNCH VEHICLE JOINT

RADIAL

CALC	OB	6APR82	REVISED	DATE	FIGURE 3.1.4
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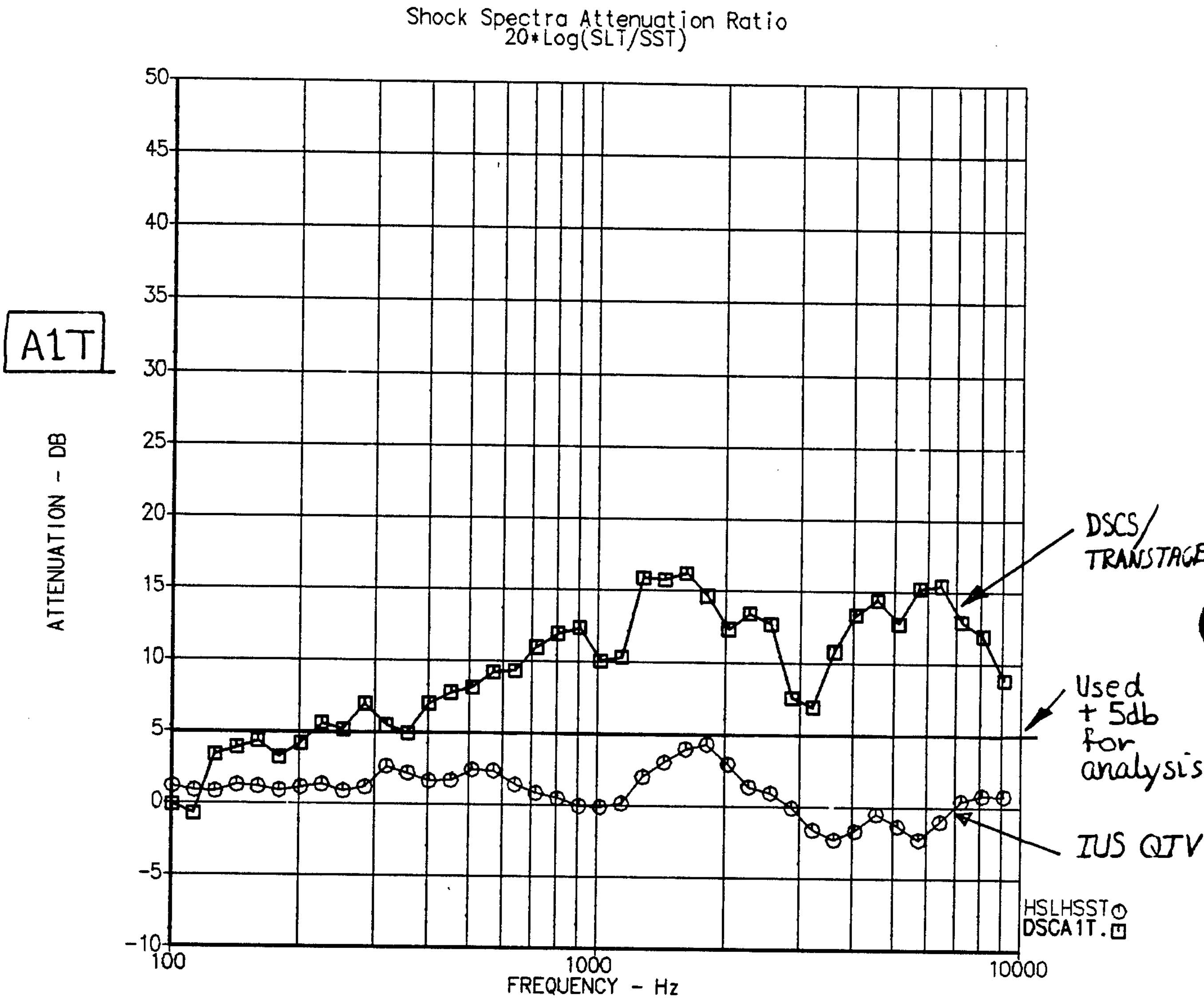
o Attenuation across IUS QTV joint between Top of ESS Longeron and Spacecraft Attach Pad on 379 Ring (HSLHSST)

□ Attenuation between DSCS Bipod Foot and Transtage Longeron, 4 Inches from interface (DSCA1T) 1981 Test



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ATTENUATION ESTIMATES SPACECRAFT TO LAUNCH VEHICLE JOINT

TANGENTIAL

CALC		6APR82	REVISED	DATE	FIGURE 3.1.5	
CHECK						
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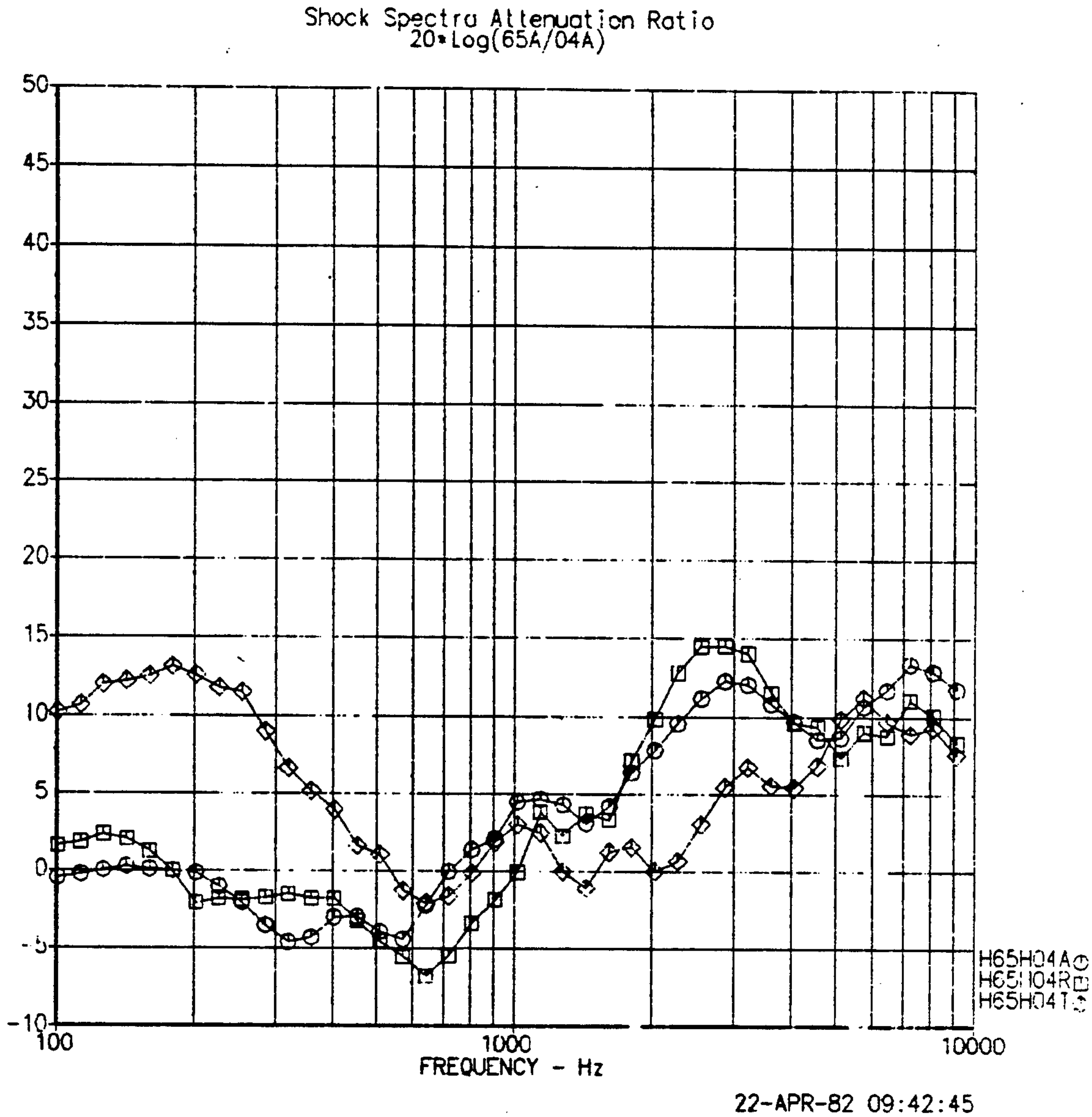
APPD.						

o Attenuation A2A
□ Attenuation A2R
◇ Attenuation A2T

A2



ATTENUATION A2

SPACECRAFT ATTACH POINT TO REM @ 189°

AXIAL
RADIAL
TANGENTIAL

CALC		22APR82	REVISED	DATE	FIGURE 3.1.6	
CHECK						
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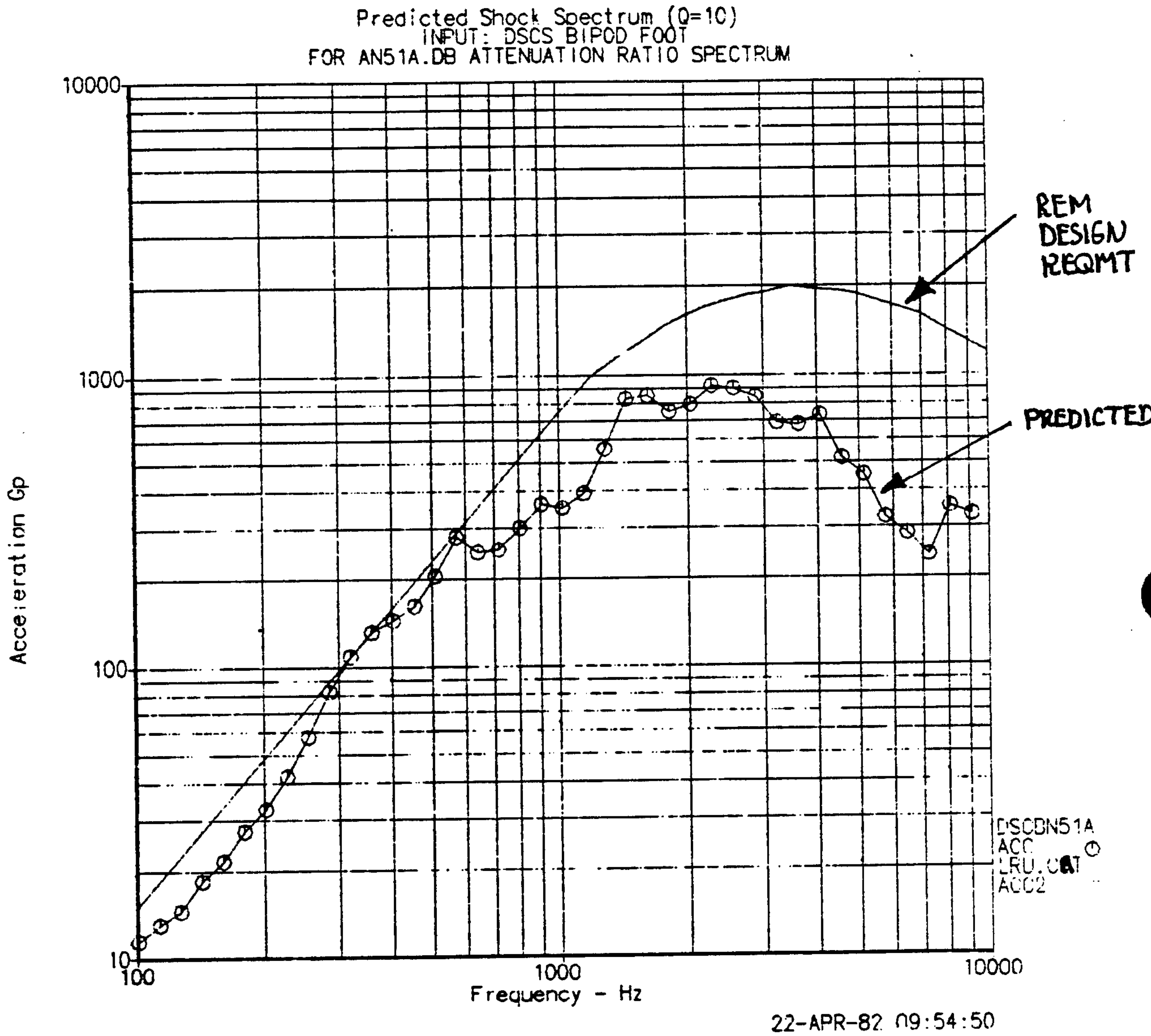
APPD.						

THE BOEING COMPANY



DSCS INDUCED SHOCK
AT IUS REM LOCATION
AXIAL

CALC	0/3	22APR82	REVISED	DATE	FIGURE 3.1.7	
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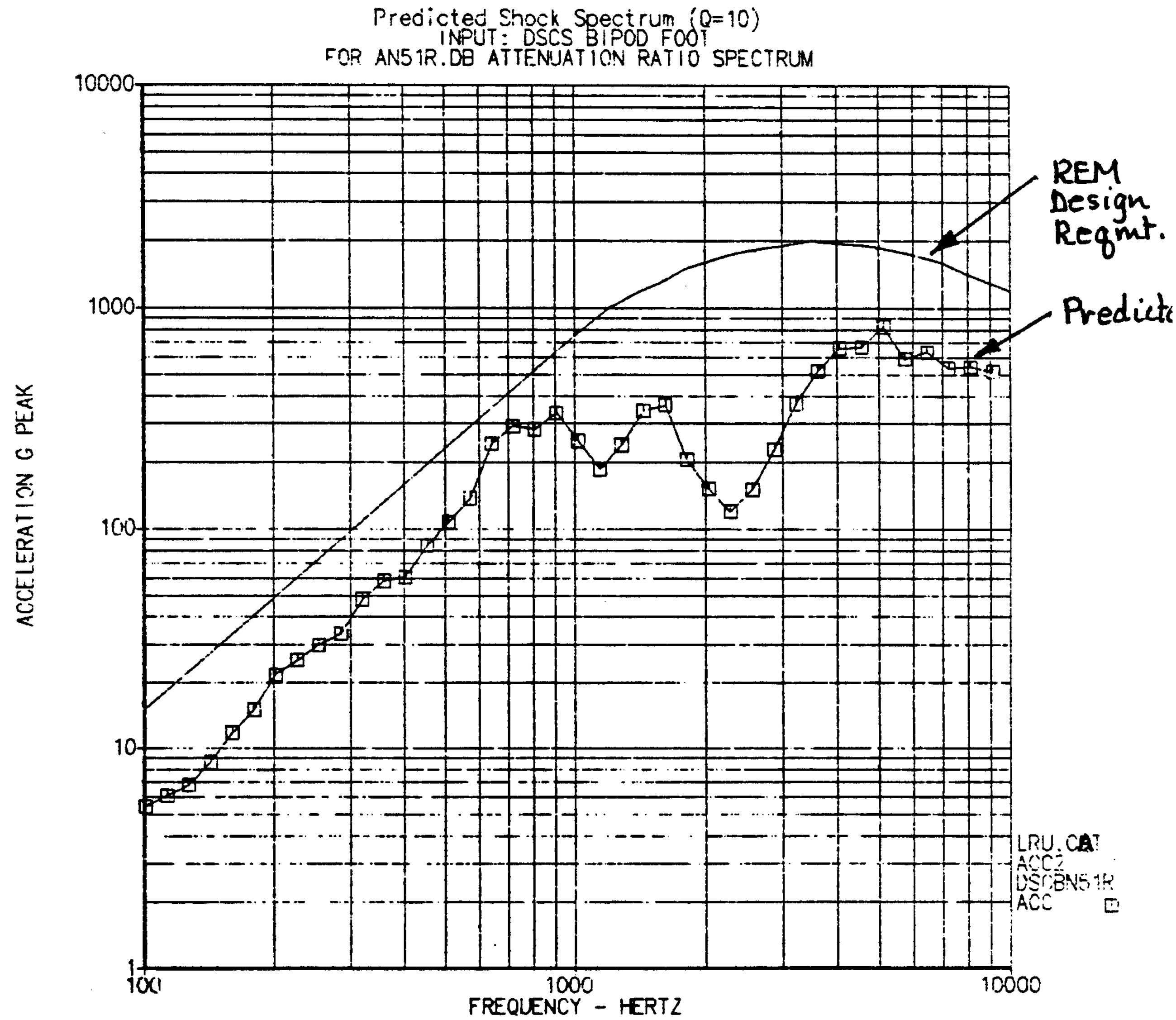
APPD.					D290-75303-2 Vol. I	



DSCS INDUCED SHOCK
AT IUS REM LOCATION
RADIAL

CALC		22APR82	REVISED	DATE	FIGURE 3.1.8
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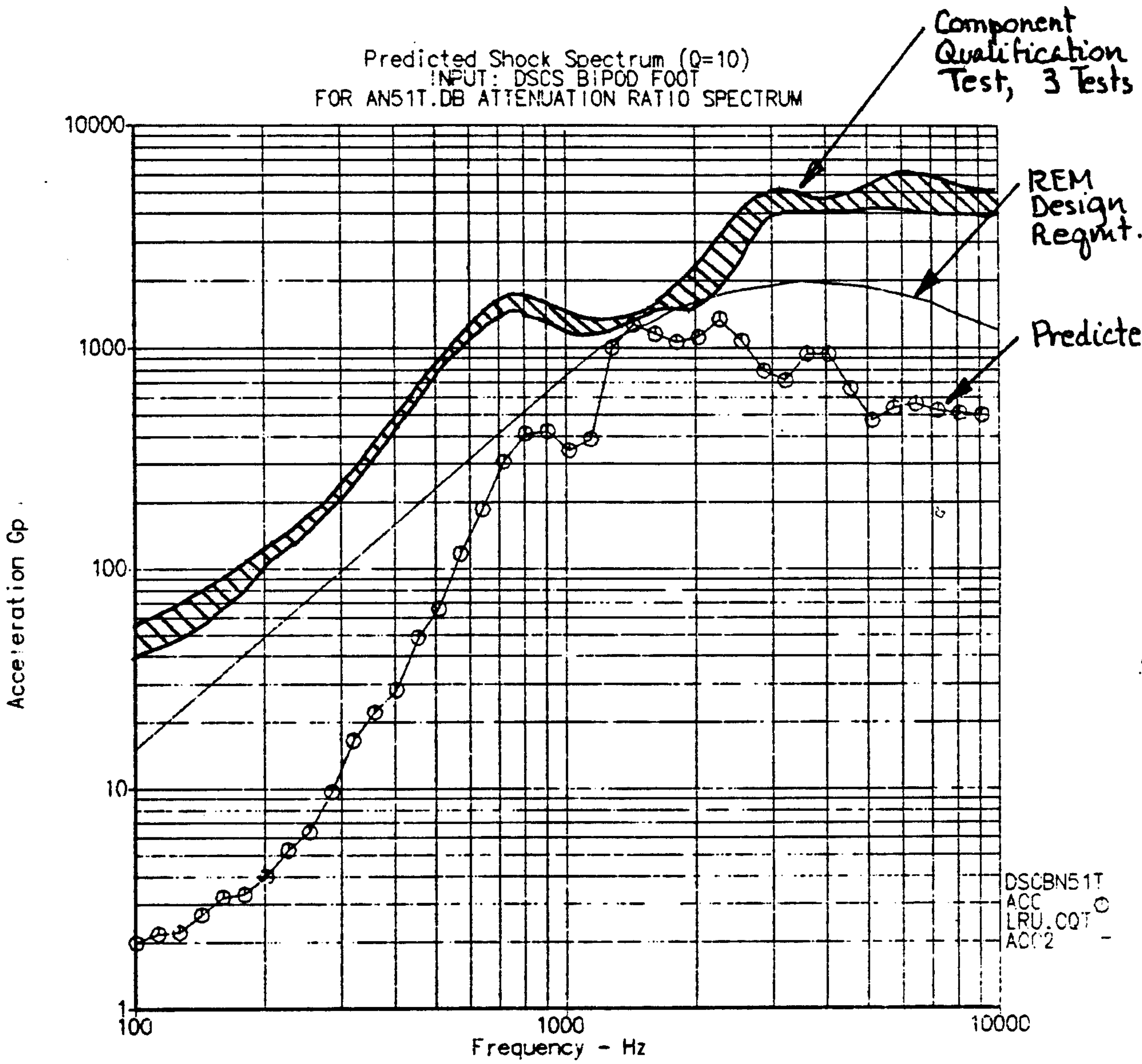
APPD.					D290-75303-2 Vol. I A



DSCS INDUCED SHOCK
AT IUS REM LOCATION

TANGENTIAL

CALC	CB	22APR82	REVISED	DATE	FIGURE 3.1.9	
CHECK						
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APPD.					THE BOEING COMPANY	PAGE B-19

3.2 Computer* Shock Prediction

The equations and data used to predict the Computer response to DSCS induced shock are shown on Figure 3.2.1. Computers are mounted on the outer conic at two different locations shown on Figure 3.2.2. The predicted computer environments are shown in Figures 3.2.5 and 3.2.6.

* BAC Drawing 290-22119/CI290025A

THE BOEING COMPANY

NUMBER
REV LTR

GENERAL EQUATION

SEE FIGURE 3.2.2

$$S_C = S_S\left(10^{\frac{-A1-A3-A4}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, see Figures 3.1.3, 3.1.4, 3.1.5.

A3 = Attenuation between ESS Longeron and Computer/IUS interface.

A4 = Attenuation across Computer shock isolators.

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.2.3

$$A3 = 20 \log \frac{(\bar{S}_{I}d)_f}{(\bar{S}_{CIN}d)_f}$$

Assumes S_I same at all longerons.
Shock path ≈ 7 in.

QTV ACCELS.	
S_I	S_{CIN}
1 AR (292.5°)	6 AR (140°)
70 AR (67.5°)	75 AR (140°)

See Figure 3.2.4

$$A4 = 20 \log \frac{(\bar{S}_{CIN}d)_f}{(\bar{S}_{COUT}d)_f}$$

QTV ACCELS.	
S_{CIN}	S_{COUT}
6AR	5A
75 AR	71R

FINAL EQUATIONS

$$S_{N15} = S_{N54} = S_S\left(10^{\frac{-A1-A3-A4}{20}}\right) \Longrightarrow$$ Predicted shock spectra shown in Figures 3.2.5, 3.2.6

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies
IN = Input at computer/IUS attach point
OUT = Output on computer side of shock isolator

FIGURE 3.2.1
COMPUTER
SHOCK EQUATIONS

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NUMBER
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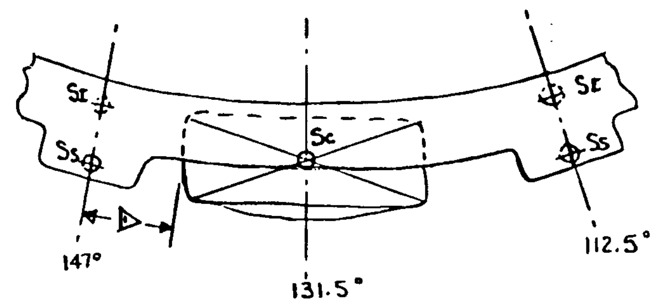
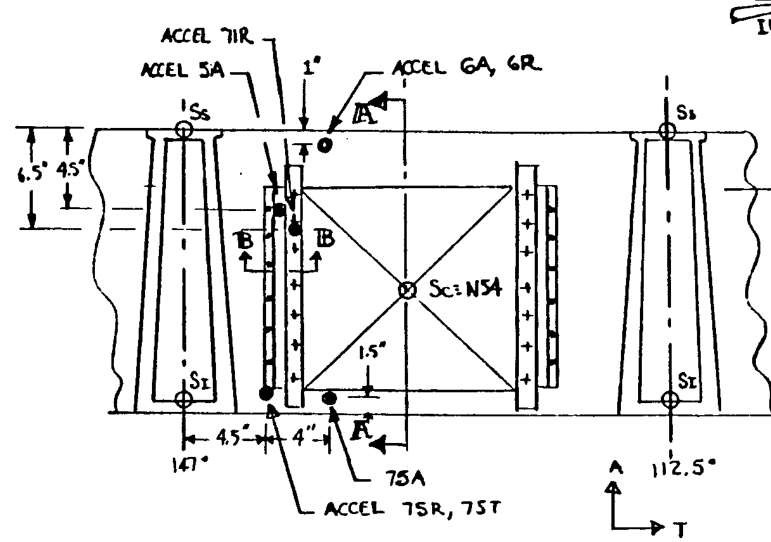
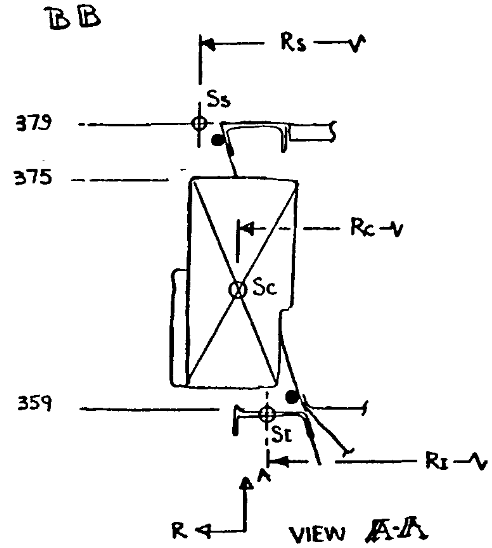
ID	COMPUTER LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH	
				SI ~ IUS			Ss ~ S/C				
	Xc	θc	Rc	XI	θI	RI	Xs	θs	Rs	I-C	S-C
N15	367	228.5	53	359	213°	51.1	379	213°	55.9	7 in.	7 in
N54	367	131.5	53	359	147°	51.1	379	147°	55.9	7 in.	7 in.

I-C = Shortest path from IUS Separation Nut (SI) to Computer / IUS Interface
S-C = Path from Ss to Sc

QTV Instrumentation on Computer N54
6A, 6R, 75A, 75R, 75T ON IUS SIDE OF SHOCK ISOLATOR
5A, 71R ON COMPUTER SIDE OF SHOCK ISOLATOR







Sc = Component Geometric Center

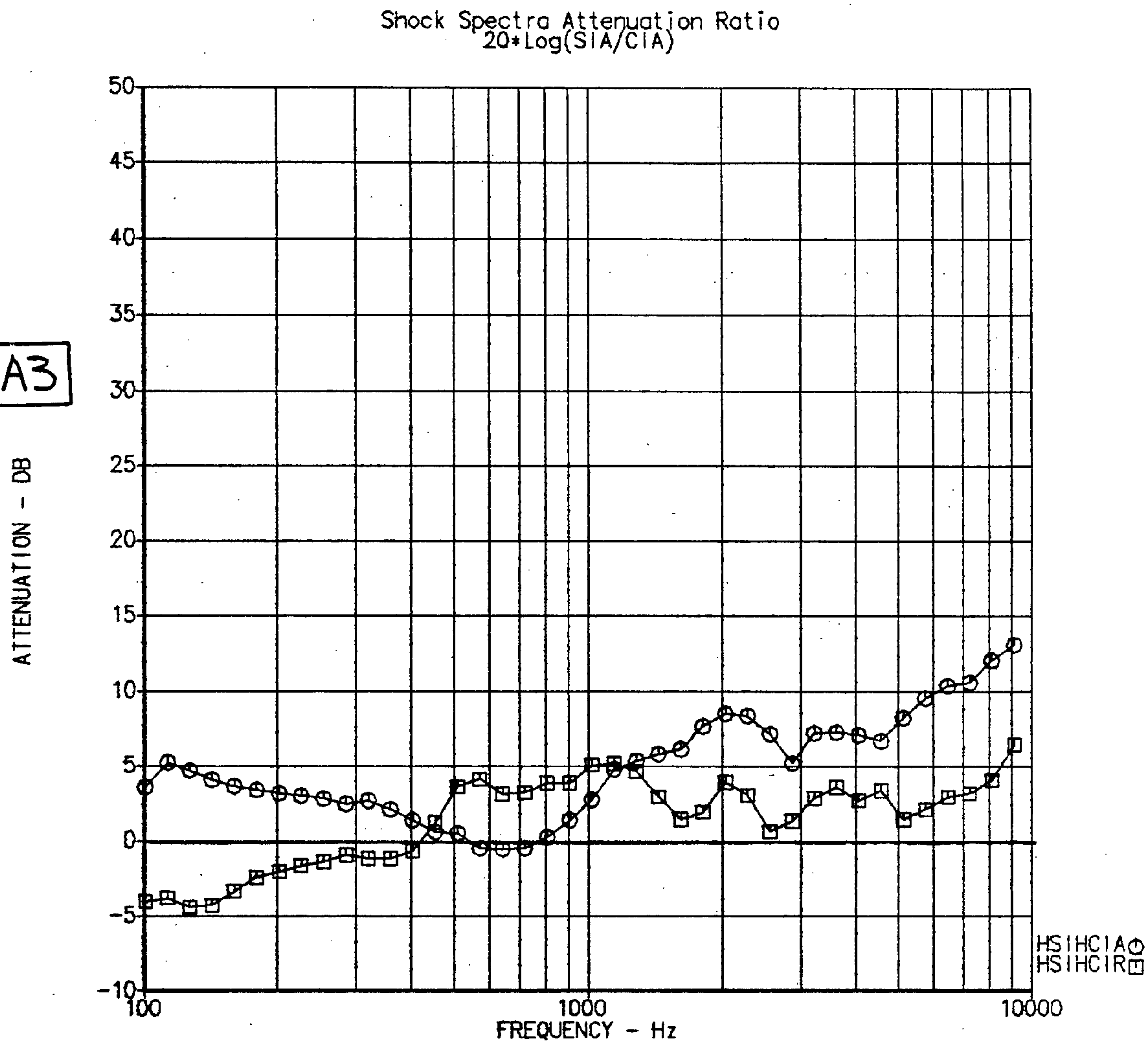
SI = IUS Shock Source
Ss = Spacecraft Shock Source
R = Radius or Radial
θ = Azimuth
X = Axial Station

FIGURE 3.2.2
COMPUTER SHOCK PATHS

Bork 4/22/82

o Attenuation A3A (Axial)
□ Attenuation A3R (Radial)

A3



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ATTENUATION A3
ESS LONGERON TO COMPUTER/IUS INTERFACE
AXIAL
RADIAL

CALC	CB	12MAR82	REVISED	DATE	FIGURE 3.2.3	
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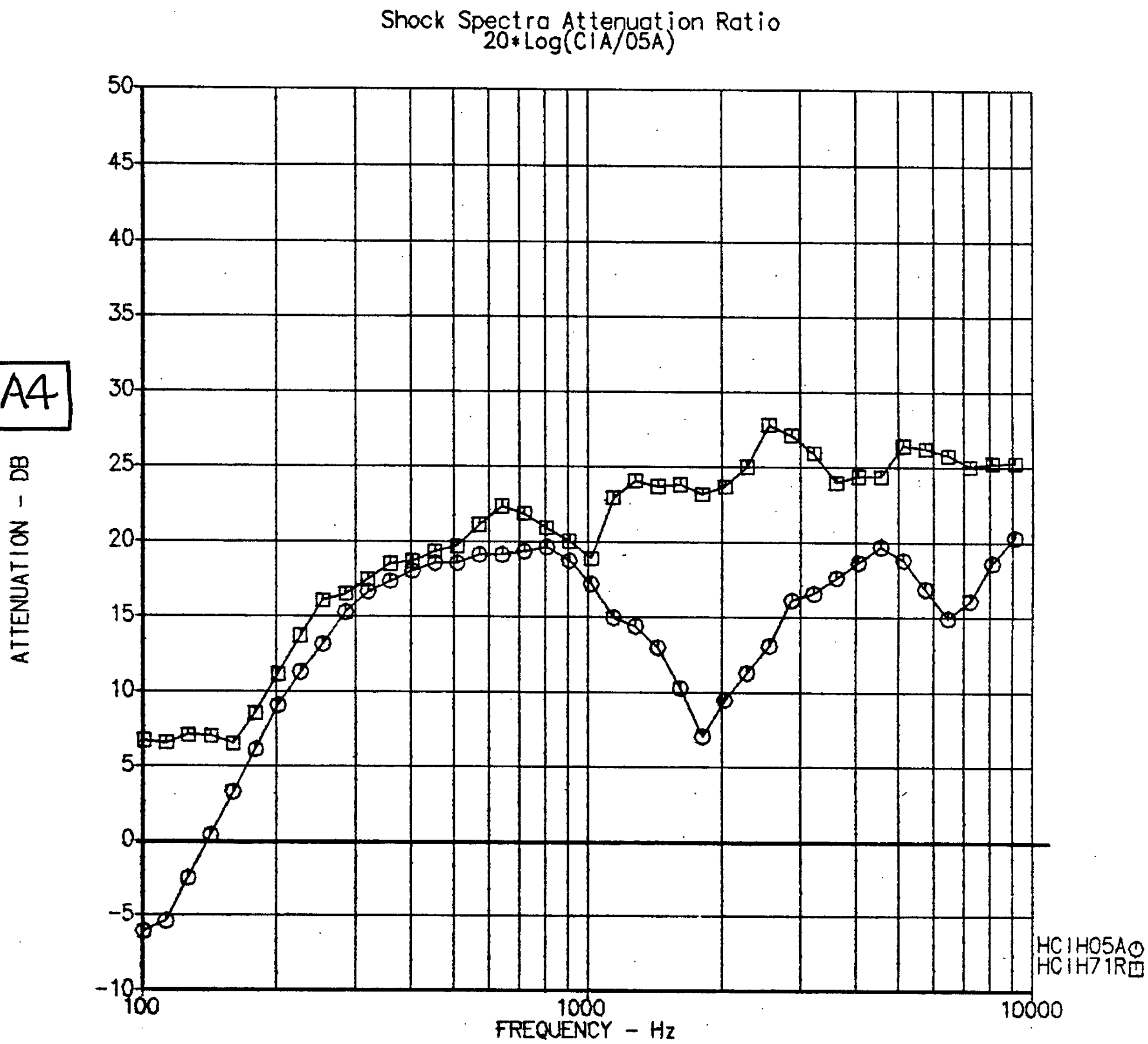
APPD.						

o Attenuation A4A (Axial)
□ Attenuation A4R (Radial)

A4



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ATTENUATION A4
ACROSS COMPUTER SHOCK ISOLATORS

AXIAL
RADIAL

CALC	CB	12MAR82	REVISED	DATE	FIGURE 3.2.4	
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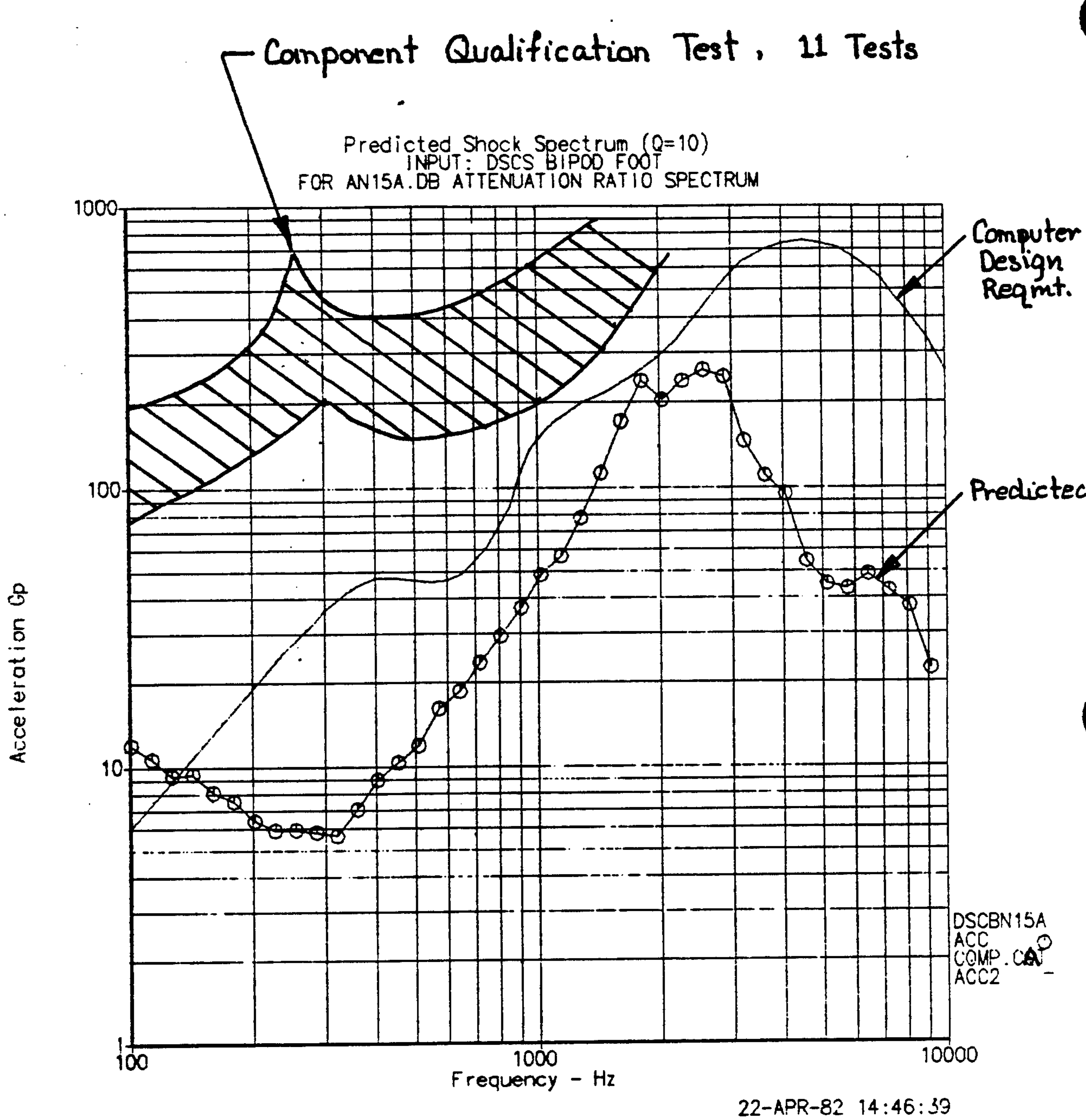

DSCS INDUCED SHOCK
AT BASE OF COMPUTER (ISOLATED SIDE)

$\boxed{\text{AXIAL}}$

CALC	GB	22APR82	REVISED	DATE	FIGURE 3.2.5	
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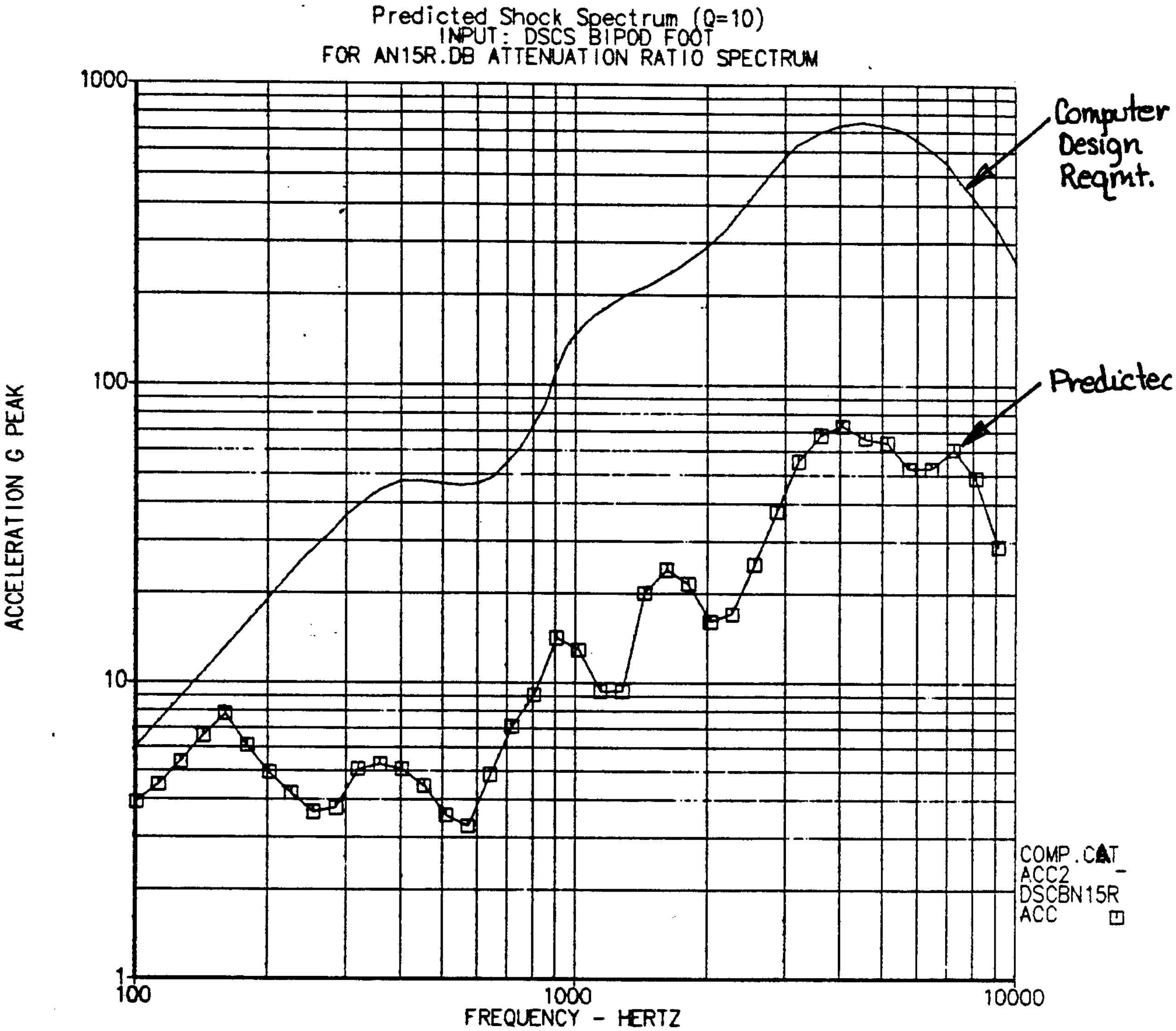
APPD.						



DSCS INDUCED SHOCK
AT BASE OF COMPUTER (ISOLATED SIDE)
RADIAL

CALC		22APR82	REVISED	DATE	FIGURE 3.2.6	
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3.3 20 Watt Amplifier* Shock Prediction

The equations and data used to predict the power amplifier response to DSCS induced shock are shown on Figure 3.3.1. The amplifiers are at two locations on the outer conic as shown in Figure 3.3.2. The predicted environments are shown in Figures 3.3.5 and 3.3.6.

* BAC Drawing 290-22121/CI290018A

THE BOEING COMPANY

NUMBER
REV LTR

GENERAL EQUATION

SEE FIGURE 3.3.2

$$S_C = S_S\left(10^{\frac{-A1-A5-A6}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, see Figures 3.1.3, 3.1.4, 3.1.5.

A5 = Attenuation between ESS Longeron and Power Amp (N28)/IUS Interface

A6 = Attenuation across Power Amp shock isolators.

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.4.3

$$A5 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{CINd})_f}$$

Assumes S_I same at all longerons
Shock path 6 in.

QTV ACCELS.	
S_I	S_{CIN}
1 AR (292.5°)	76 AR (332°)
70 AR (67.5°)	

See Figure 3.4.4

$$A6 = 20 \log \frac{(\bar{S}_{CINd})_f}{(\bar{S}_{COUTd})_f}$$

QTV ACCELS	
S_{CIN}	S_{COUT}
23 AR	40 AR
76 AR ▷	73 AR ▷

▷ Not used in calculation

FINAL EQUATIONS

$$S_{N28} = S_S\left(10^{\frac{-A1-A5-A6}{20}}\right) \Longrightarrow$$

Predicted shock spectra are shown in Figure 3.3.5

Calculations for N28 only since it is closest to shock source
d = A, R

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies
IN = Input at Power Amplifier / IUS attach point
OUT = Output on Power Amplifier Side of shock isolator

FIGURE 3.3.1
POWER AMPLIFIERS
SHOCK EQUATIONS

CBuh 4/22/82

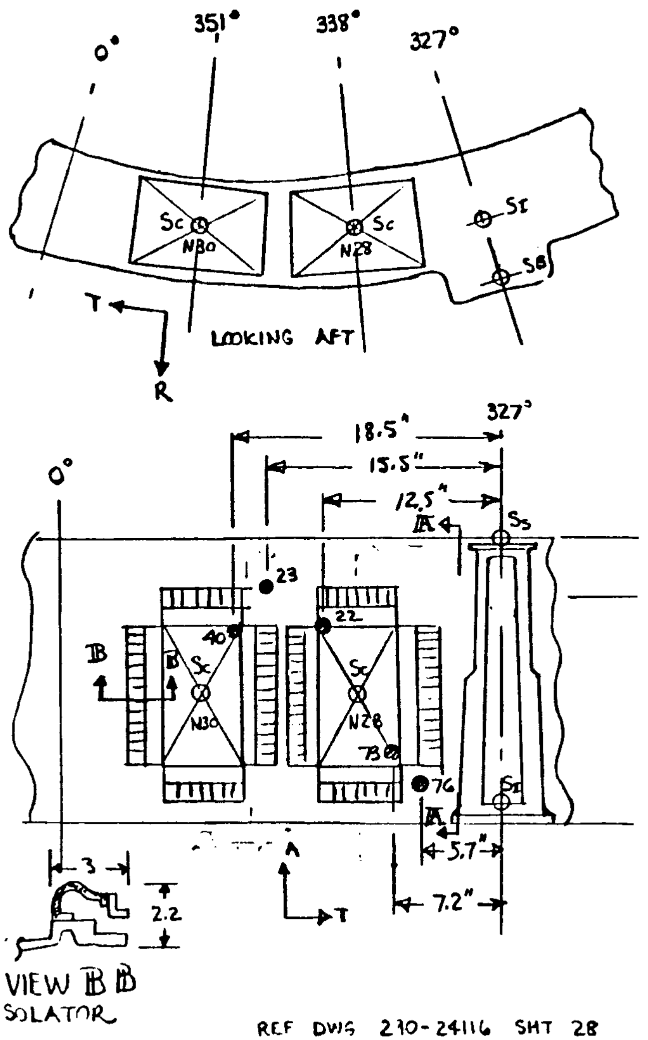
THE BOEING COMPANY

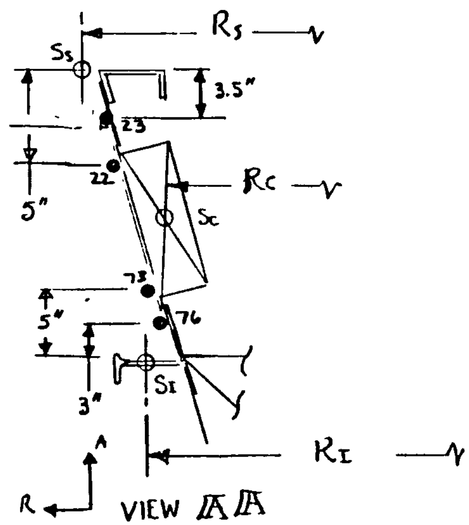
NUMBER
REV LTR

ID	POWER AMPLIFIER LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH ▷1	
				S_I IUS			S_S S/C				
	X_C	θ_C	R_C	X_I	θ_I	R_I	X_S	θ_S	R_S	I-C	S-C
N28 (A)	369	338°	50.5	359	327°	51.1	379	327°	55.9	6"	6"
N30 (B)	369	351°	50.5	359	327°	51.1	379	327°	55.9	16"	16"

▷1 I-C = Path from IUS Sep Nut to Power Amp / IUS Interface
S-C = Path from Ss to Power Amp / IUS Interface

QTV Instrumentation
22A, 22R, 73A, 73R on N28 Side of Shock Isolator
40A, 40R, 40T on N30 Side of Shock Isolator
{23A, 23R; 76A, 76R, 76T} on IUS side of Shock Isolator





Sc = Component Geometric Center

SI = IUS Shock Source
Ss = Spacecraft Shock Source
R = Radius
θ = Azimuth
X = Axial Station

FIGURE 3.3.2
POWER AMPLIFIER
SHOCK PATHS

[illegible] 4/22/82

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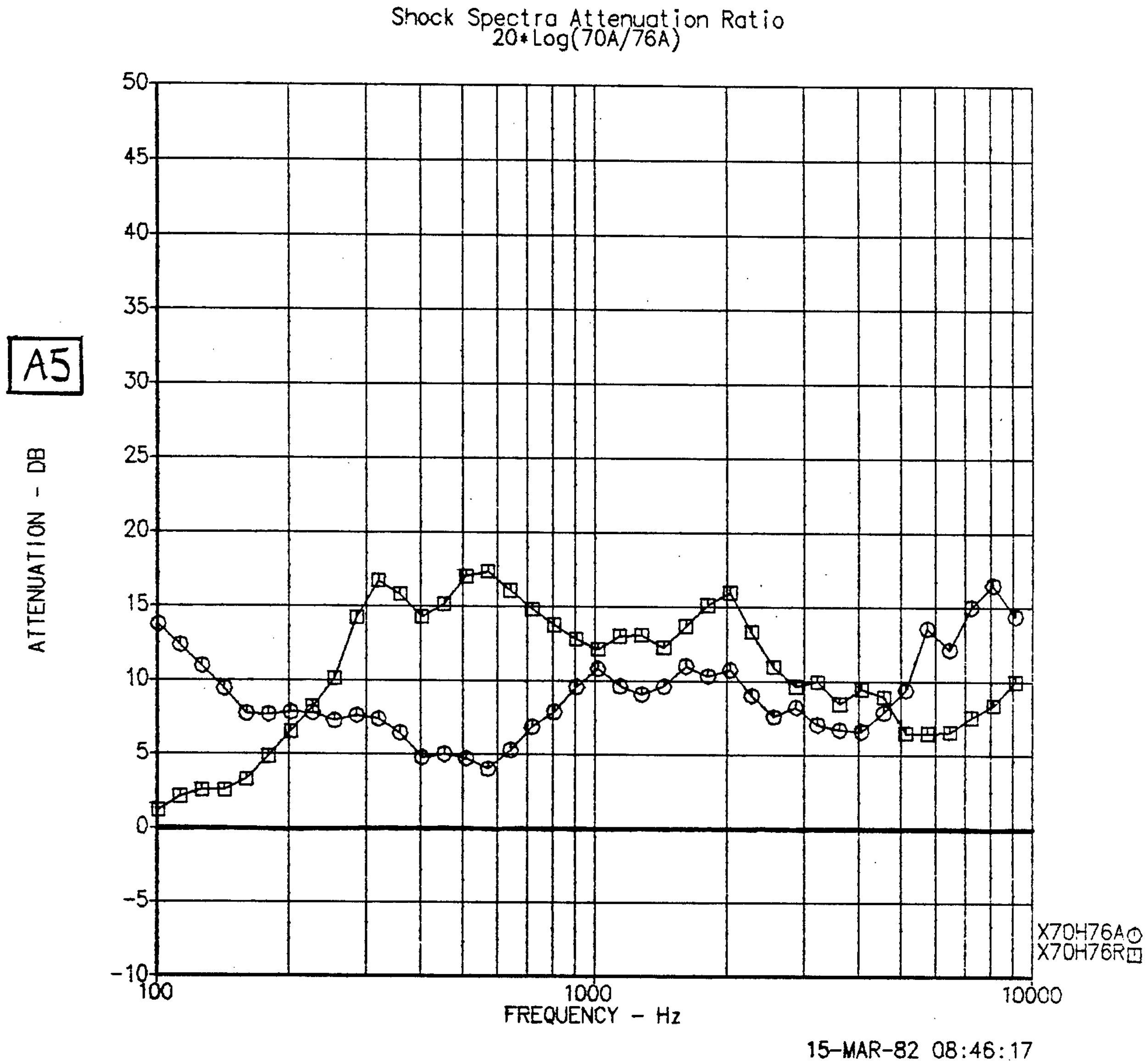
○ Attenuation A5A (Axial)
□ Attenuation A5R (Radial)



ATTENUATION A5

ESS LONGERON TO POWER AMP/IUS INTERFACE

AXIAL
RADIAL

CALC	OB	15MAR82	REVISED	DATE	FIGURE 3.3.3	
CHECK						
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APPD.					D290-75303-2 Vol. I A	PAGE B-30

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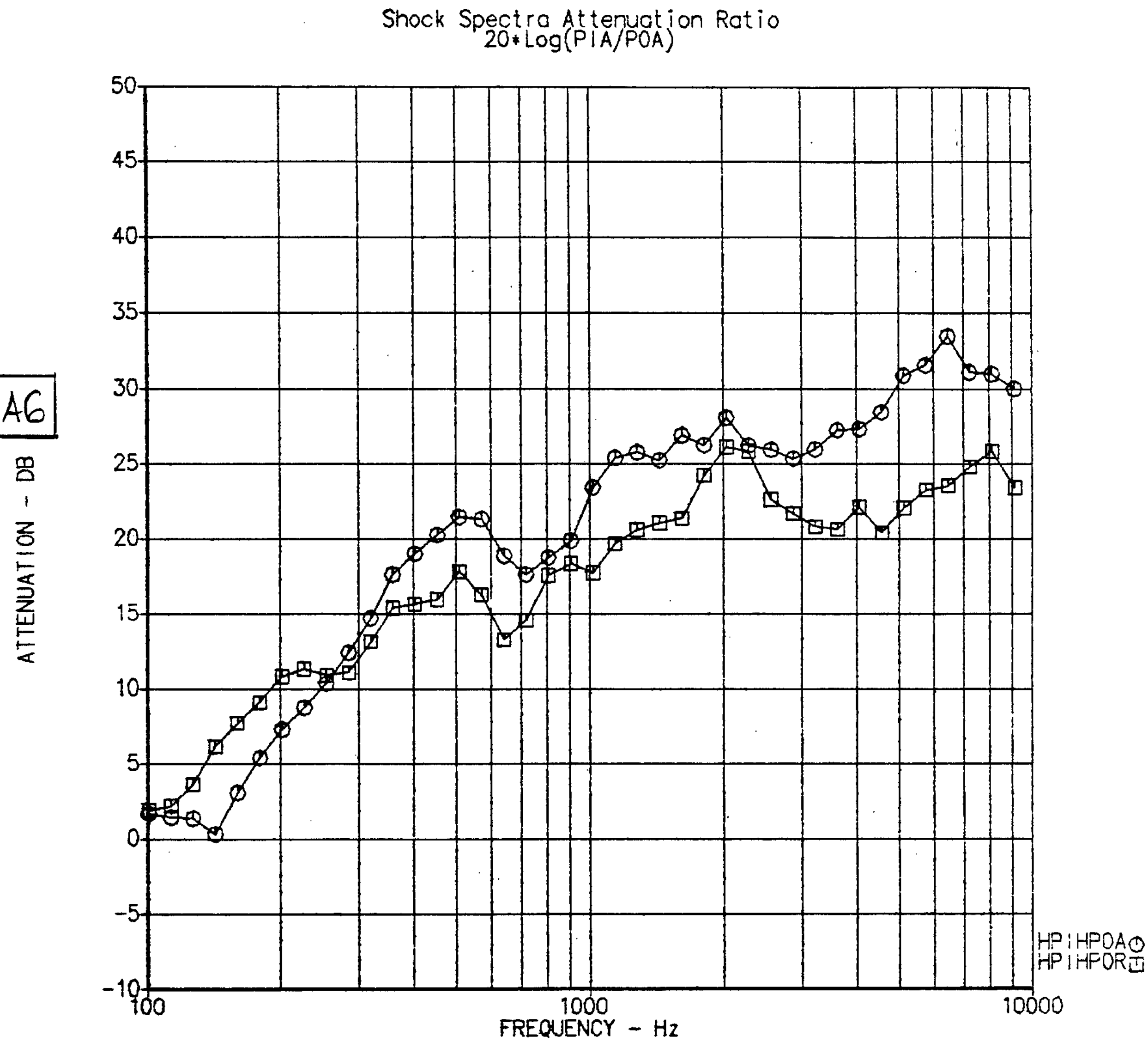
o Attenuation A6A (Axial)
□ Attenuation A6R (Radial)

A6



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ATTENUATION A6
ACROSS POWER AMP SHOCK ISOLATORS

CALC	ep	15MAR82	REVISED	DATE	FIGURE 3.3.4	
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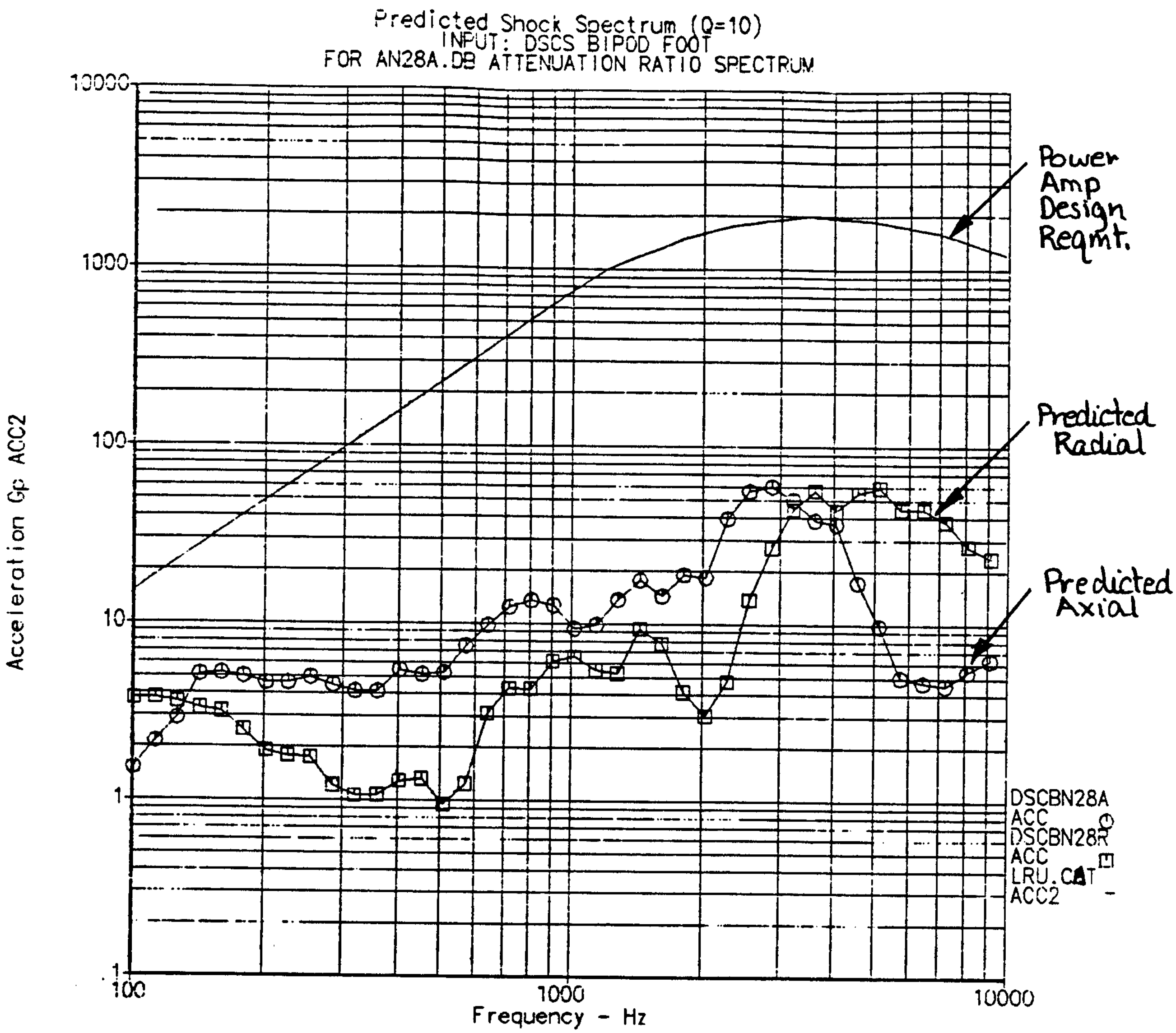

DSCS INDUCED SHOCK
AT BASE OF POWER AMPLIFIER (ISOLATED SIDE)

AXIAL
RADIAL

CALC	C/3	23APR82	REVISED	DATE	FIGURE 3.3.5
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3.4 Shock Prediction, SIU*, Transponder*, EMU* (Inner Conic)

The equations and data used to predict the SIU, Transponder and EMU Shock response are shown on Figure 3.4.1. All of these equipment items are located on the Inner Conic structure at the locations shown in Figure 3.4.2. The predicted environments were calculated only for the SIU and Transponder A locations. The Transponder is closer to the shock source than the other equipment items. The predicted environments for the SIU and EMU will be less than the Transponder environment. The SIU environment was calculated because it has a lower design requirement. The predicted environments are shown in Figures 3.4.4 through 3.4.7.

* SIU, BAC Drawing 290-26199/CI290199A
Transponder, BAC Drawing 290-22121/CI290018A
EMU, BAC Drawing 290-22224

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GENERAL EQUATION SEE FIGURE 3.4.2

$$S_c = S_s\left(10^{-\frac{A1-A9-A10-AB}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, see Figs. 3.1.3, 3.1.4, 3.1.5.
A9 = Attenuation between IUS Sep Nut and Inner-Conic Structure.
A10 = Attenuation between top of ESS Longeron and IUS Sep Nuts, See Fig 3.5.3.
AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

- S_C = Shock level on Component (Calculated)
- S_{NX} = Shock level on Specific Component, NX (Calculated)
- S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
- S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
- S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.
- A = Calculated Attenuation in decibels
- $\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

- d = Shock direction (A = Axial, R = Radial, T = Tangential)
- f = 1/6 octave band center frequencies

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.4.3

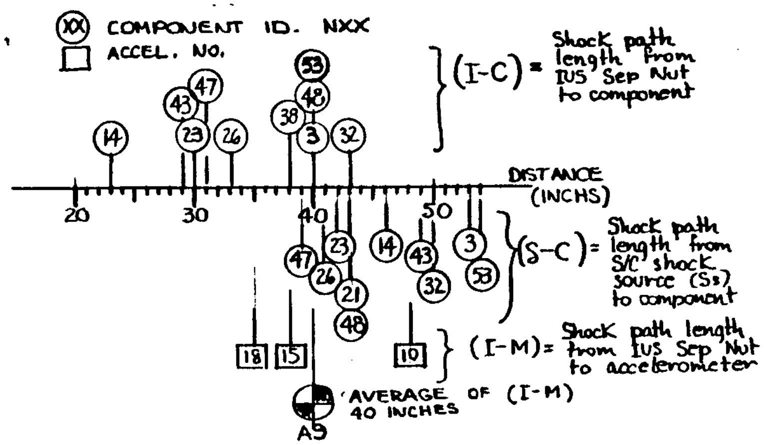
$$A9 = 20 \log \frac{(\bar{S}_I d)_f}{(\bar{S}_C d)_f}$$

- Assumes S_I same at all longerons
- Shock path 40 in. average

QTV ACCELS	
S_I	S_C
1 ART	10 ART
70 ART	15 ART
	18 ART

$$AB = 20 \log \frac{(I-C)}{40}$$

COMPONENT	Inches I-C	db AB
N3	40	0
N14 XPONDER A	25	-4.8
N21	38	-0.5
N23 EMU	30	-2.5
N26	33	-1.7
N32	42	+0.4
N43	29	-2.8
N47 SIU	31	-2.2
N48	23	-4.8
N53 XPONDER B	40	0



FINAL EQUATIONS

$$S_{N14} = S_s\left(10^{\frac{-A1-A9-A10+4.8}{20}}\right)$$

$$S_{N23} = S_s\left(10^{\frac{-A1-A9-A10+2.5}{20}}\right)$$

$$S_{N47} = S_s\left(10^{\frac{-A1-A9-A10+2.2}{20}}\right)$$

Predicted shock spectra are shown on Figures 3.4.4 thru 3.4.7

FIGURE 3.4.1
INNER CONIC EQUIPMENT
SHOCK EQUATIONS

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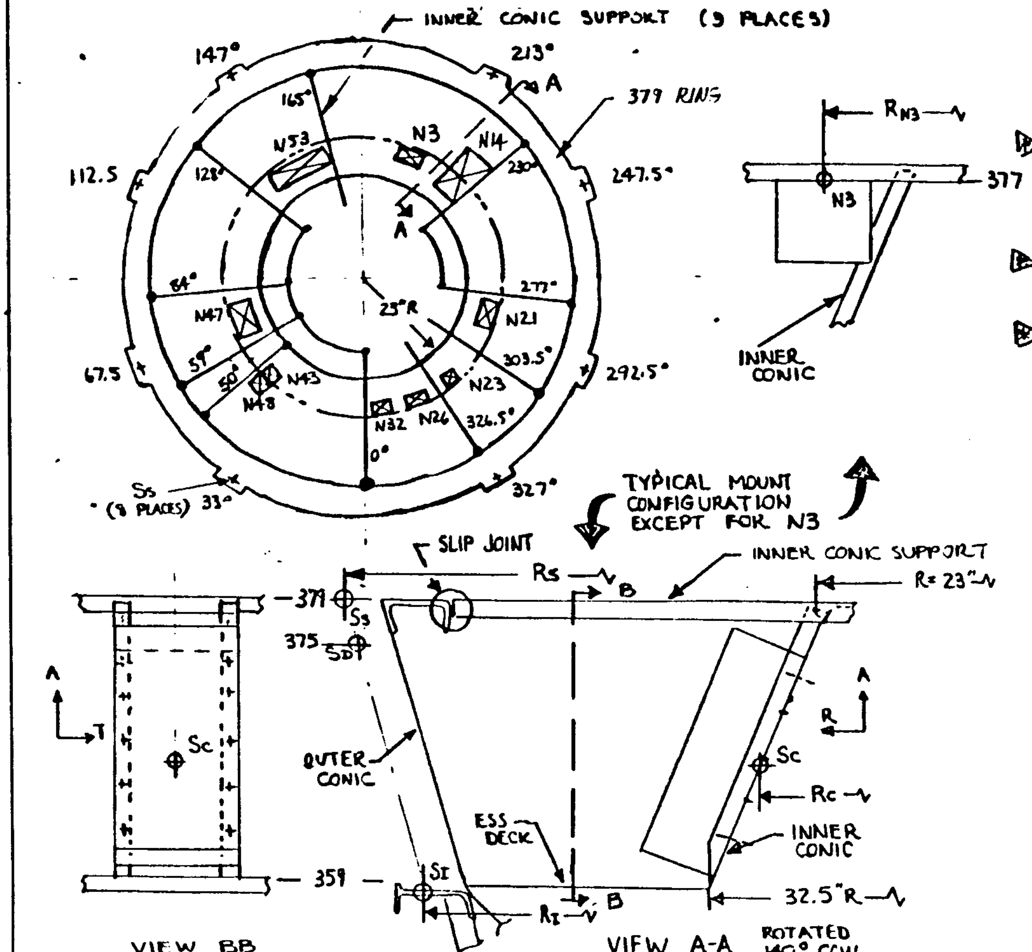
NOTE: 371 RING TO INNER CONIC SUPPORT ATTACH IS A SLIP JOINT THEREFORE PRIMARY SHOCK PATH FROM S/C IS FROM Ss THRU LONGERON AND DECK TO INNER CONIC



COMPONENT		LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH-INCHS ▷	
					SI - IUS			Ss - S/C				
ID	NAME	Xc	Θc	Rc	XI	ΘI	RI	Xs	Θs	Rs	I-C	S-C
N3	TVC B	377	203°	31°	359	213	51	379	213	56	40/4	53/4
N14	TRANSPONDER A	368	225°	28°	↓	213	↓	↓	213	↓	23/2	46/2
N21	TVC A	375	290°	24		292.5			292.5		38/3	43/3
N23	EMU	367	320.5°	30		327			327		30/3	42/3
▷ N26	DECRYPTOR A	371.5	336°	30		327			327		33/3	41/3
N32	DECRYPTOR B	371.5	353°	30		327			327		42/3	50/3
N43	ENCRYPTOR A	370	46°	28		33			33		29/2	49/2
▷ N47	SIU	371	71.5	27		67.5			67.5		31/2	39/2
N48	ENCRYPTOR B	365	46°	31		33			33		23/2	55/2 43/3
▷ N53	TRANSPONDER B	374	146.5°	25	↓	147	↓	↓	147	↓	40/3	54/3

▷ I-C = Shortest path from SI to Sc / Number of joints
S-C = Shortest path from SS to Sc / Number of joints

Sc = Geometric Center of Component Mount Plane
So = Spacecraft Shock Defined
SI = IUS Shock Source
Ss = Spacecraft Shock Source
R = Radius Θ = Azimuth X = Axial Station

▷ QTV INSTRUMENTATION						
ACCEL.	COMPONENT	XM	ΘM	RM	PATH I-M	LENGTH S-M
10ART	N53	377	131°	26	47/3	61/3
15ART	N47	375	63°	27	38/2	40/2
18ART	N26	375	330°	32	35/3	43/3

A = AXIAL
R = RADIAL
T = TANGENTIAL

I-M = Shortest Path from SI to Measurement (M) / No. of joints
S-M = " " " Ss to M / No. of joints

FIGURE 3.4.2
INNER CONIC
SHOCK PATHS

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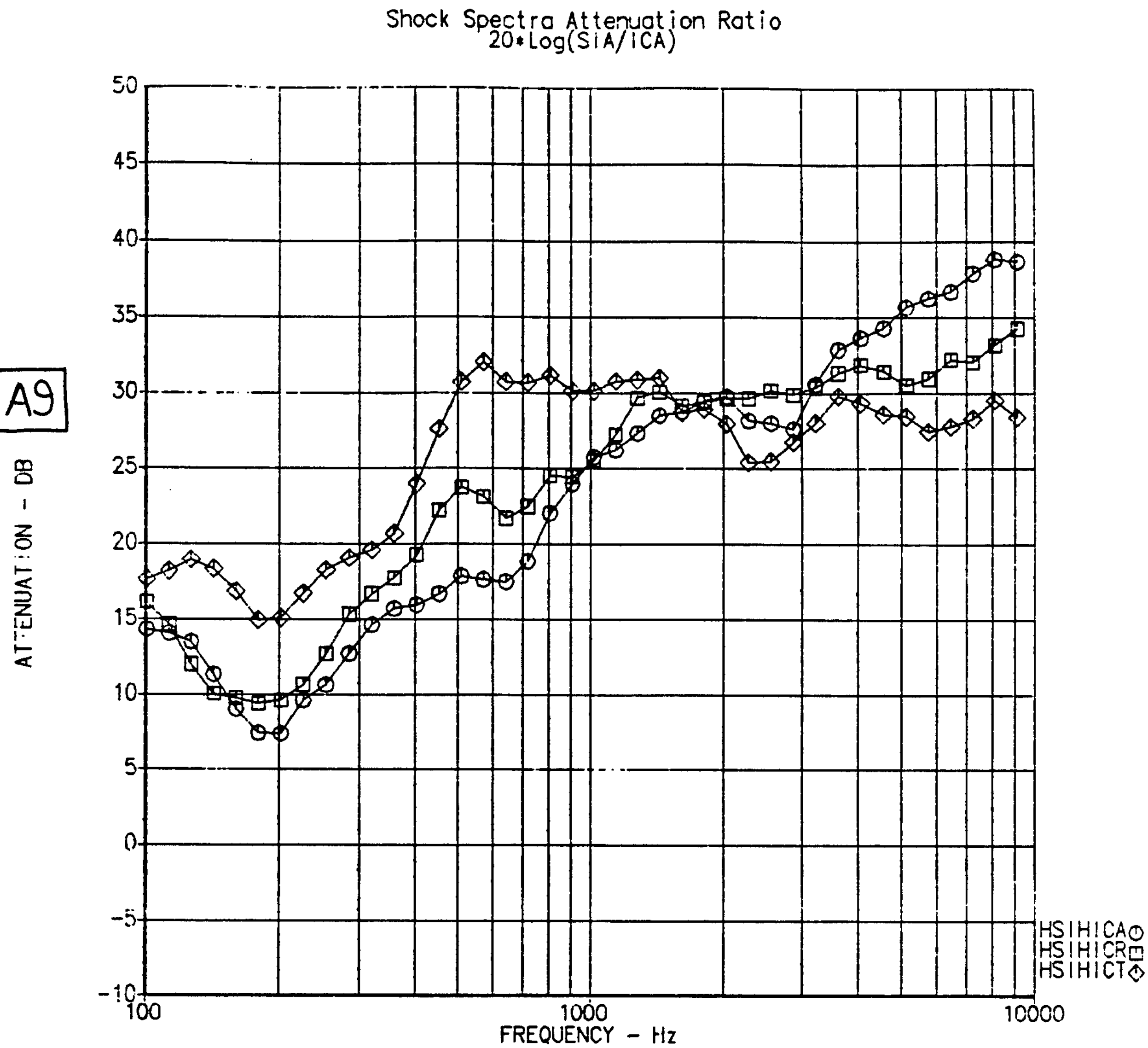
O Attenuation A9A (Axial)
□ Attenuation A9R (Radial)
◇ Attenuation A9T (Tangential)

A9



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ATTENUATION A9
BETWEEN IUS SEP NUT AND INNER CONIC

AXIAL
RADIAL
TANGENTIAL

CALC	CB	23APR82	REVISED	DATE	FIGURE 3.4.3
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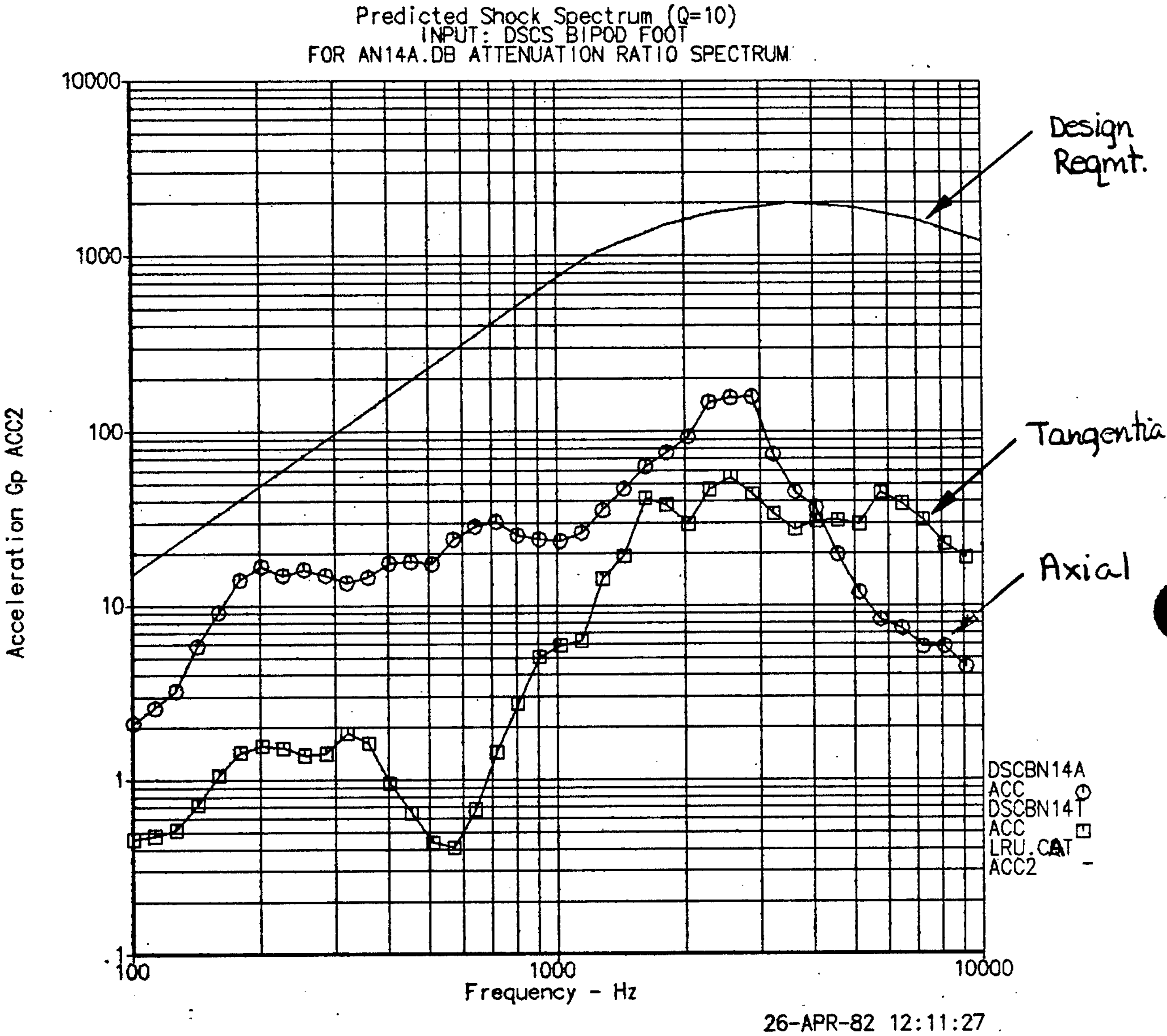

PREDICTED VS. DESIGN REQUIREMET
DSCS INDUCED SHOCK
AT TRANSPONDER LOCATION

AXIAL
TANGENTIAL

CALC	CJB	26APR82	REVISED	DATE	FIGURE 3.4.4	
CHECK						
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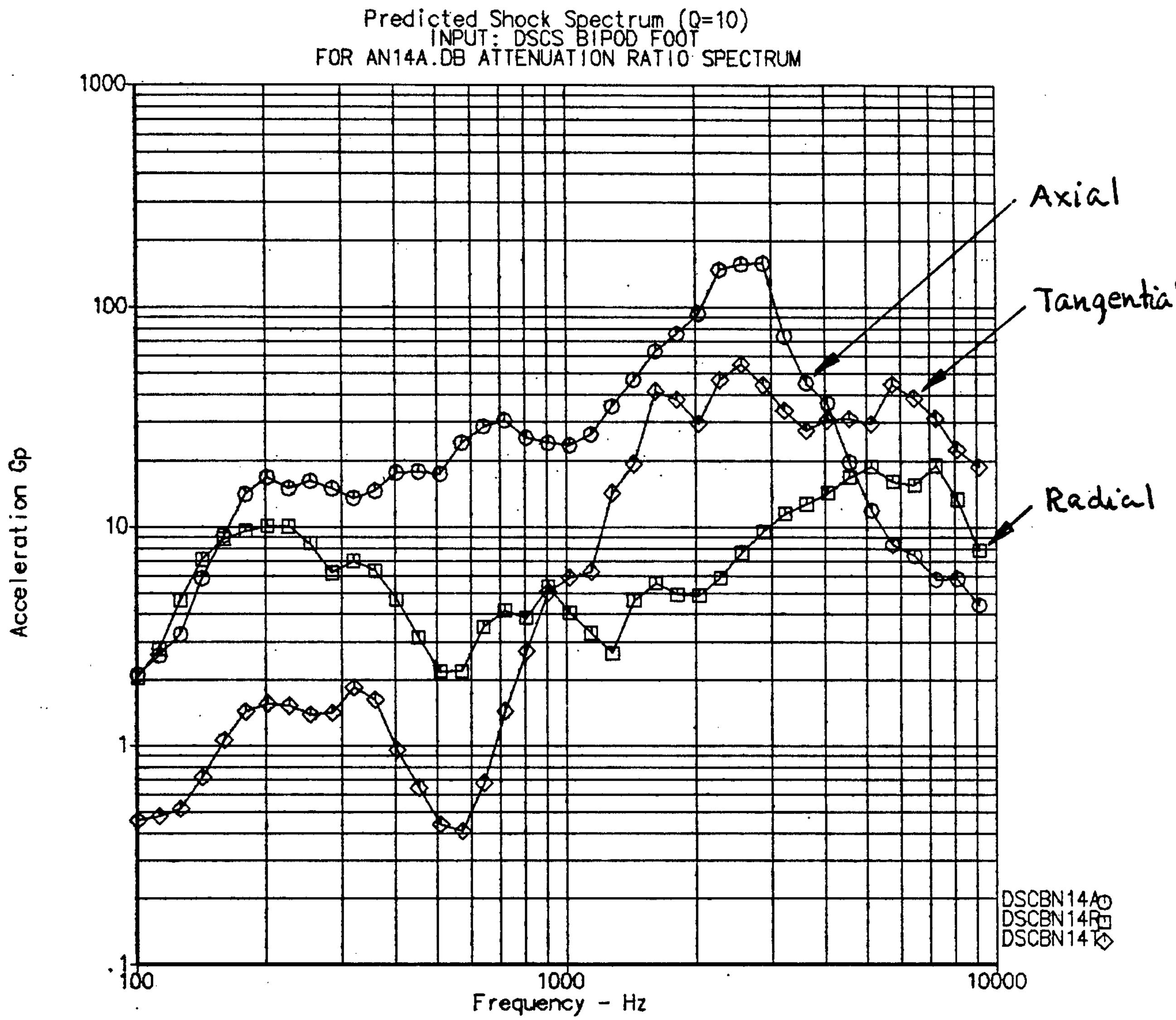
APPD.					THE BOEING COMPANY	PAGE B-37



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PREDICTED DSCS INDUCED SHOCK
AT TRANSPONDER LOCATION

AXIAL
RADIAL
TANGENTIAL

CALC	CB	26APR82	REVISED	DATE	FIGURE 3.4.5	
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APPD.					THE BOEING COMPANY	PAGE B-38

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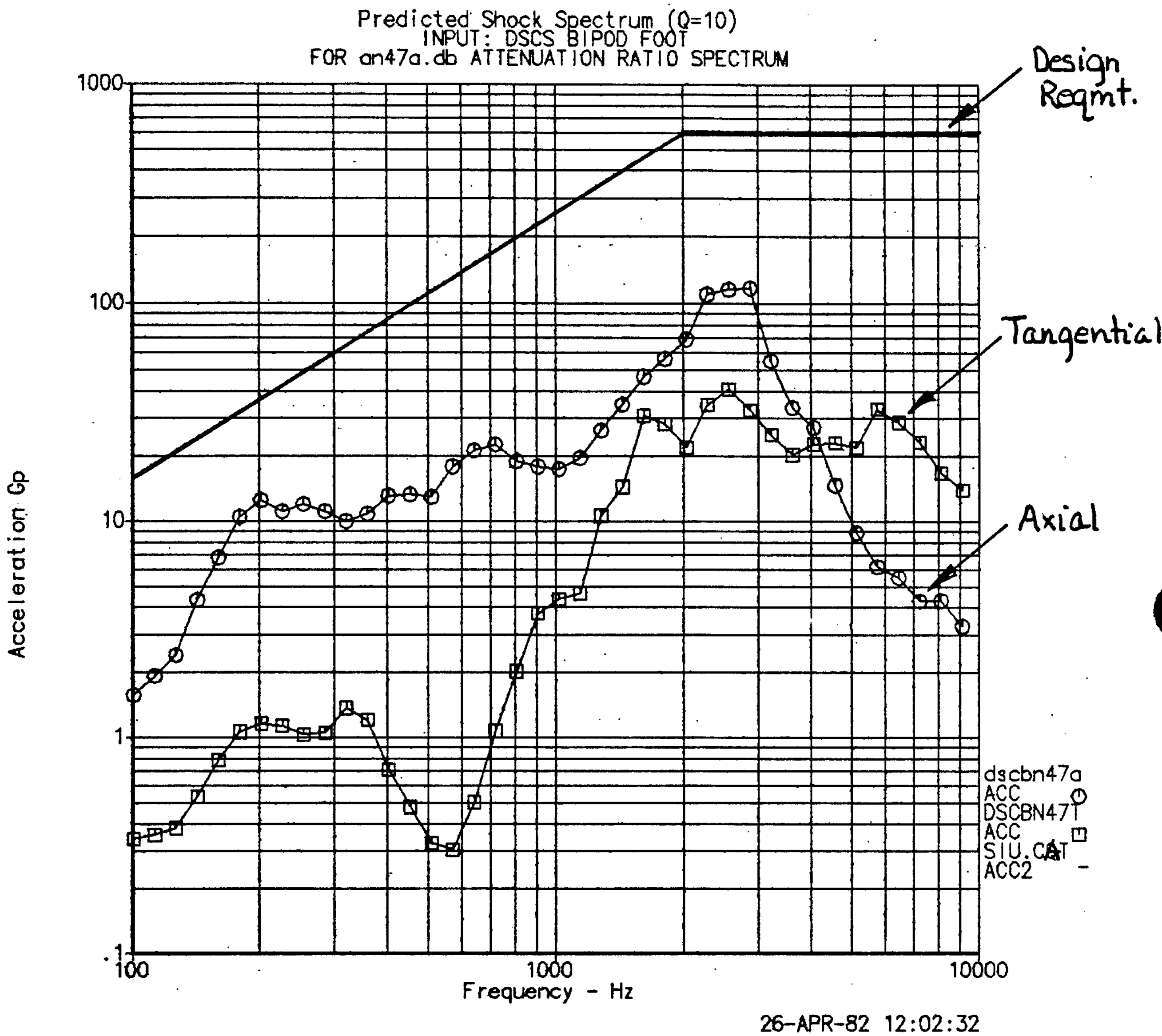

PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT SIU LOCATION

AXIAL
TANGENTIAL

CALC	DJB	26APR82	REVISED	DATE	FIGURE 3.4.6	
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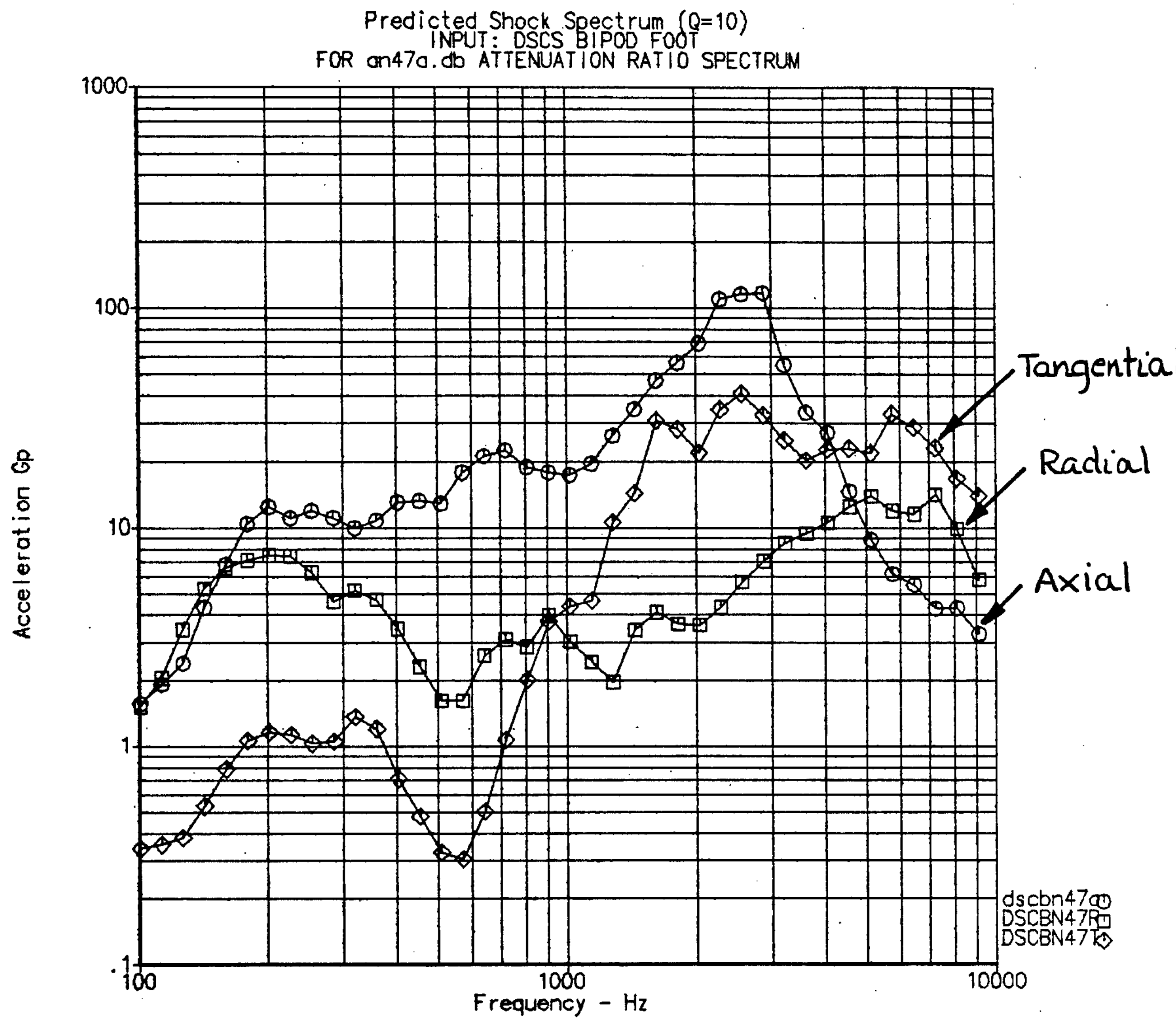

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PREDICTED DSCS INDUCED SHOCK
AT SIU LOCATION

AXIAL
RADIAL
TANGENTIAL

CALC	CB	26APR82	REVISED	DATE	FIGURE 3.4.7	
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APPD.					D290-75303-2 Vol. I A	PAGE B-40

3.5 ESS Batteries* Shock Prediction

The equations and data used to predict the shock environment on the ESS batteries are shown on Figure 3.5.1. The battery locations are shown on Figure 3.5.2. The predicted environments for the batteries closest to the shock source are shown in Figure 3.5.5.

* BAC Drawing 290-22212

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GENERAL EQUATION   SEE FIGURE 3.5.2

$$S_C = S_S\left(10^{-\frac{A1-A10-A11-AB}{20}}\right)$$

A1 = Attenuation across IUS/spacecraft joint, see Figs 3.1.3, 3.1.4, 3.1.5.
A10 = Attenuation between top of ESS Longeron and IUS Sep Nut
A11 = Attenuation between IUS Sep Nut and Battery attach point.
AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts
d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies

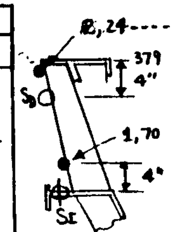
APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.5.3

$$A10 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{Ld})_f}$$

- Assumes S_I same for all longerons
- Shock path = 16 in.

QTV ACCELS	
S_I	S_L
1 ART	2 ART
70 ART	24 AR
	25 ART
	37 ART
	39 A



$$AB = 20 \log \frac{(I-C)}{21}$$

See Figure 3.5.4

$$A11 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{cd})_f}$$

- Assumes S_I same for all longerons
- Shock path = 21 in.

QTV ACCELS	
S_I	S_C
1 RT	7 RT
70 RT	

ID.	INCHES I-C	DB AB
N4	14	-3.5
N5	20	-0.4
N6	26	+1.9
N9	14	-3.5
N10	20	-0.4
N11	26	+1.9

I-C = Shock path from IUS Sep Nut to Battery Attach point.

FINAL EQUATIONS

$$S_{N4} = S_{N9} = S_S\left(10^{-\frac{A1-A10-A11+3.5}{20}}\right)$$

$$S_{N5} = S_{N10} = S_S\left(10^{-\frac{A1-A10-A11+0.4}{20}}\right)$$

$$S_{N6} = S_{N11} = S_S\left(10^{-\frac{A1-A10-A11-1.9}{20}}\right)$$

Predicted shock spectra shown on Figure 3.5.5

FIGURE 3.5.1
ESS BATTERIES
SHOCK EQUATIONS

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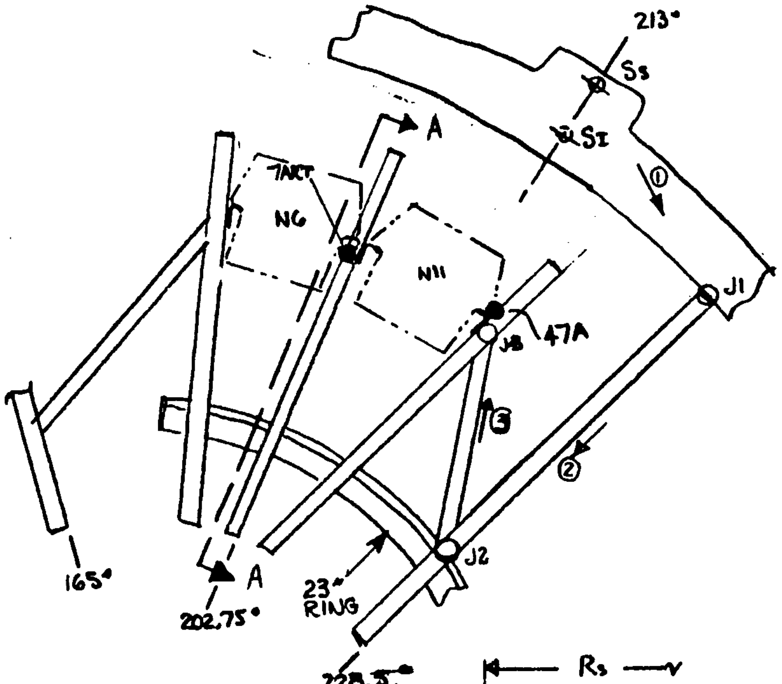

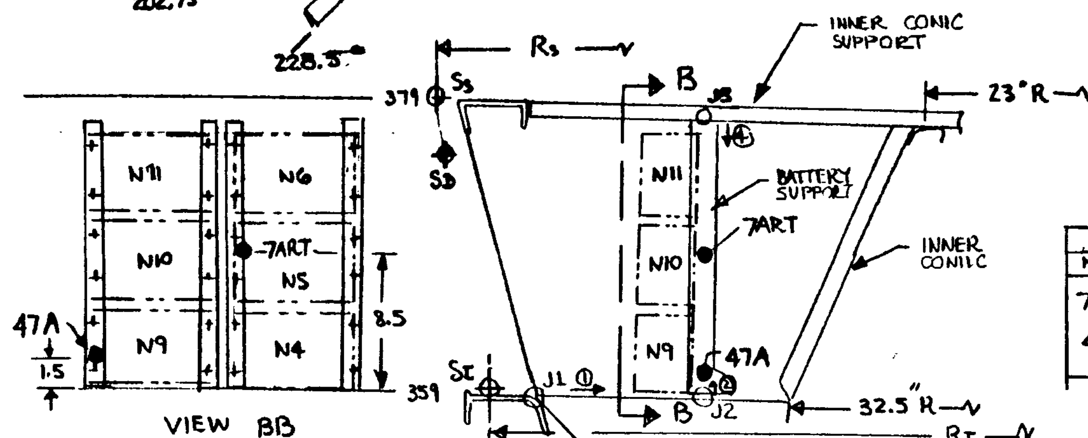

VIEW AA ROTATED 112.75° CCW

SHOCK PATH CALCULATIONS

IUS SOURCE (SI) TO NEAREST BATTERY (I-C)

① From 213° Nut (SI) thru Joint 1 across deck to Battery Support	13"
② Thru Joint 2 up Battery Support to first Battery Attach Point (N9)	1"

I-C = TOTAL 14" 2 JOINTS

Spacecraft source (Ss) to nearest battery via Inner Conic support structure (S-C)₁

① From 213° Spacecraft Attach Point (Ss) to Inner Conic Support @ 228.5°	17"
② Thru Joint 1 along support to 23" Ring	25"
③ Thru Joint 2 along Brace to Battery Support	15"
④ Thru Joint 3 along Battery Support to first Battery Attach Point (N11)	1"

$(S-C)_1$ = ~~TOTAL 58" 3 JOINTS~~

Spacecraft source (Ss) to battery via longeron $(S-C)_2$

① From 213° Ss thru longeron/ring joint to longeron, along longeron, to 359 joint	20"
② Across deck, up support to Battery N9	14"

$(S-C)_2$ = TOTAL 34" 3 JOINTS

QTV INSTRUMENTATION		
NO.	I-M	D-M
7ART	21"/2	37"/2
47A	14"/2	30"/2

I-M = Shortest Path from SI to Accel. (M)/No. of joints.

D-M = Shortest Path SD to M/joints.

FIGURE 3.5.2
ESS BATTERIES
SHOCK PATHS

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SHEET

D1 4802 8100 ORG 1/71

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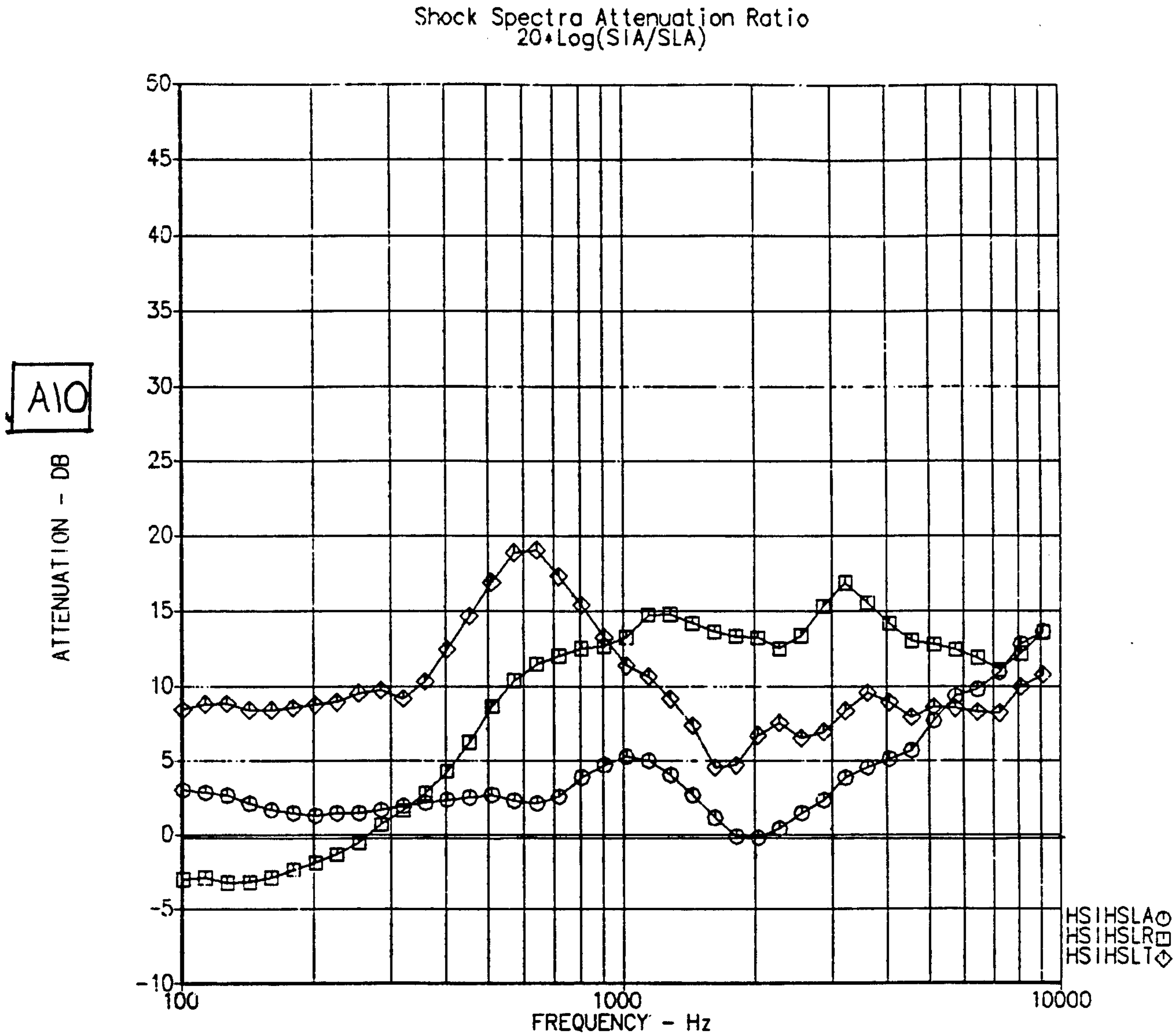
o Attenuation A10A (Axial)
□ Attenuation A10R (Radial)
◇ Attenuation A10T (Tangential)



ATTENUATION A10
BETWEEN TOP OF ESS LONGERON
AND IUS SEP NUT

AXIAL
RADIAL
TANGENTIAL

CALC	CB	23APR82	REVISED	DATE	FIGURE 3.5.3	
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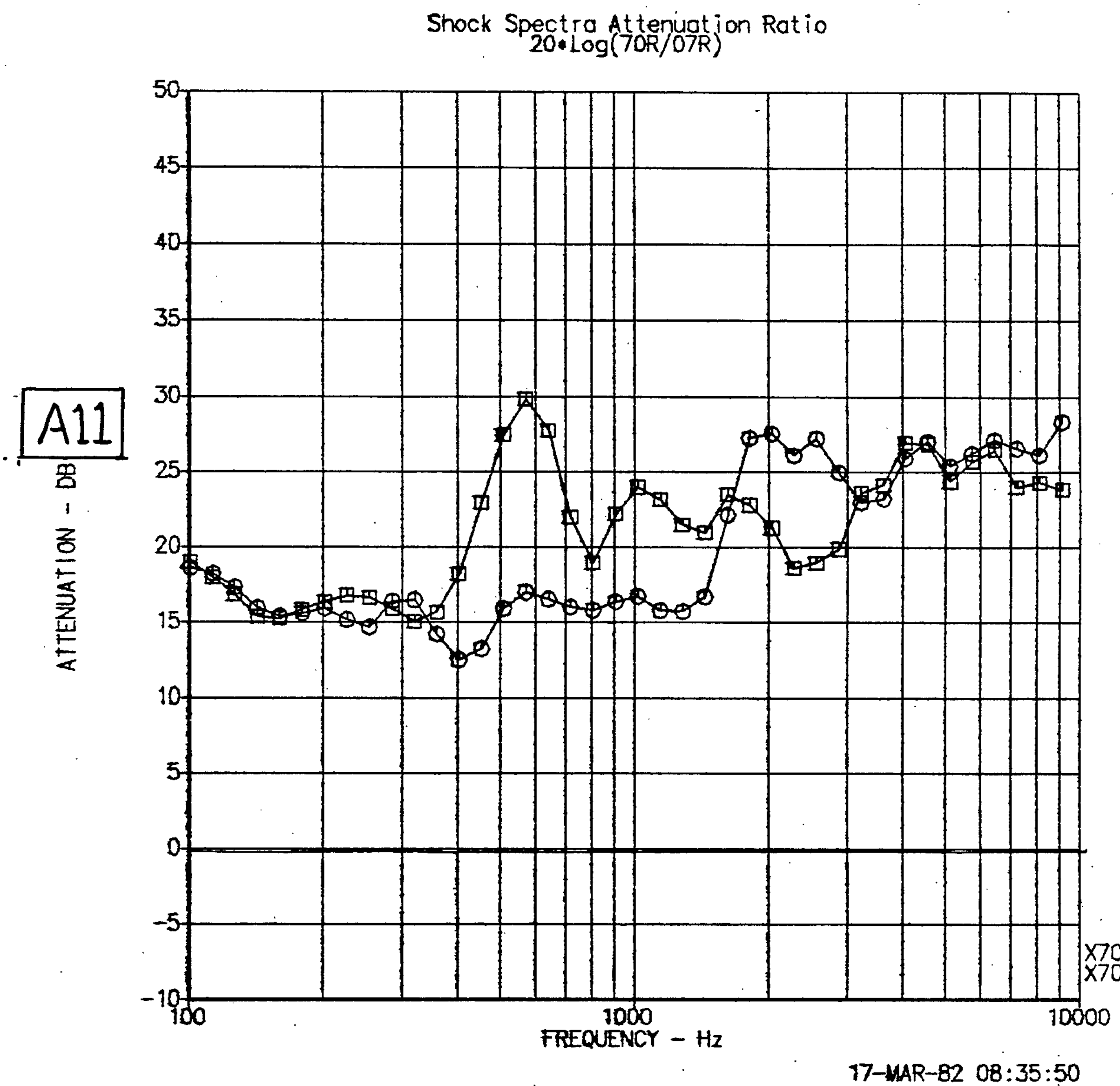
○ A11A (AXIAL)
□ A11R (RADIAL)



ATTENUATION A11
BETWEEN IUS SEP NUT AND BATTERY

CALC		17MAR82	REVISED	DATE	FIGURE 3.5.4	
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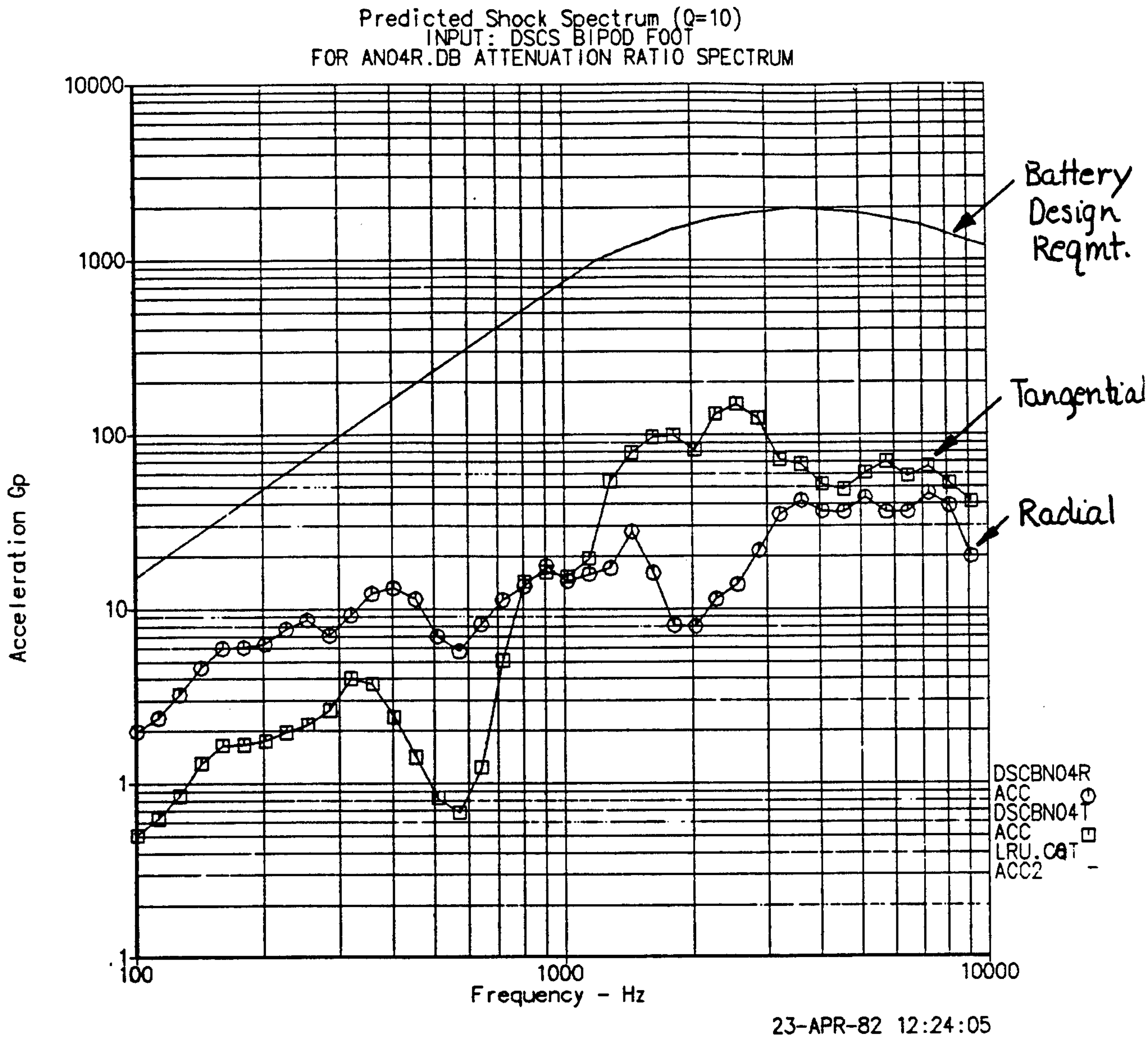

PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT BATTERY LOCATION, ESS

RADIAL
TANGENTIAL

CALC	GS	23APR82	REVISED	DATE	FIGURE 3.5.5
CHECK					
APPD.					
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3.6 Shock Prediction, RCS*, IMU*, SCU*, PDU* (ESS Deck)

The equations and data used to predict shock environments for equipment mounted on the ESS deck are shown on Figure 3.6.1. The locations of the equipment are shown on Figure 3.6.2. Figures 3.6.5 through 3.6.9 contain predicted shock spectra for the PDU, RCS and SCU. The IMU prediction is not shown since it is similar but less than the RCS prediction.

* RCS Manifold, BAC Drawing 290-21031
RCS Tank, BAC Drawing 290-21007
RCS Resistor Board, BAC Drawing 290-21066

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NUMBER
REV LTR

GENERAL EQUATION SEE FIGURE 3.6.2

$$S_C = S_S\left(10^{\frac{-A1-A10-A12-A13-AB}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, Figs 3.1.3, 3.1.4, 3.2.5

A10 = Attenuation between top of ESS Longeron and IUS Sep Nut, Fig. 3.5.3

A12 = Attenuation between IUS Sep Nut and ESS Deck.

A13 = Attenuation across PDU isolator.

AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Fig. 3.6.3

$$A12 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{Cd})_f}$$

- Assumes S_I same at all longerons
- Shock path 16 in average

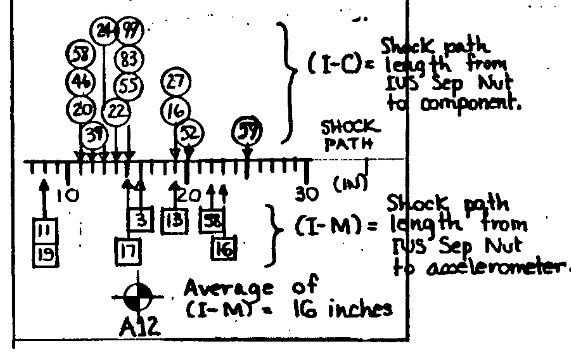
QTV ACCELS	
S_I	S_C
1 ART 70 ART	3 ART 11 ART 13 AR 16 ART 17 ART 19 ART 58 R

See Fig. 3.6.4

$$A13 = 20 \log \frac{(\bar{S}_{CIN d})_f}{(\bar{S}_{COUT d})_f}$$

QTV ACCELS	
S_{CIN}	S_{COUT}
13 AR	12 AR

○ Component ID □ Accel. No.



$$AB = 20 \log \frac{(I-C)}{16}$$

	ID.	INCHES I-C	db AB
RCS	N16	19	+1.5
PDU	N20	11	-3.2
PDU	N22	14	-1.2
	N24	13	-1.8
	N27	19	+1.5
RCS	N39	12	-2.5
SCU	N46	11	-3.2
RCS	N52	20	+1.9
	N55	15	-0.6
	N58	11	-3.2
IMU	N59	25	+3.9
	N83	15	-0.6
	N99	15	-0.6

FINAL EQUATIONS

$$S_{N20} = S_S\left(10^{\frac{-A1-A10-A12-A13+3.2}{20}}\right)$$

$$S_{N39} = S_S\left(10^{\frac{-A1-A10-A12+2.5}{20}}\right)$$

$$S_{N46} = S_S\left(10^{\frac{-A1-A10-A12+3.2}{20}}\right)$$

Predicted shock spectra shown on Figures 3.6.5 thru 3.6.9

FIGURE 3.6.1
ESS DECK EQUIPMENT
SHOCK EQUATIONS

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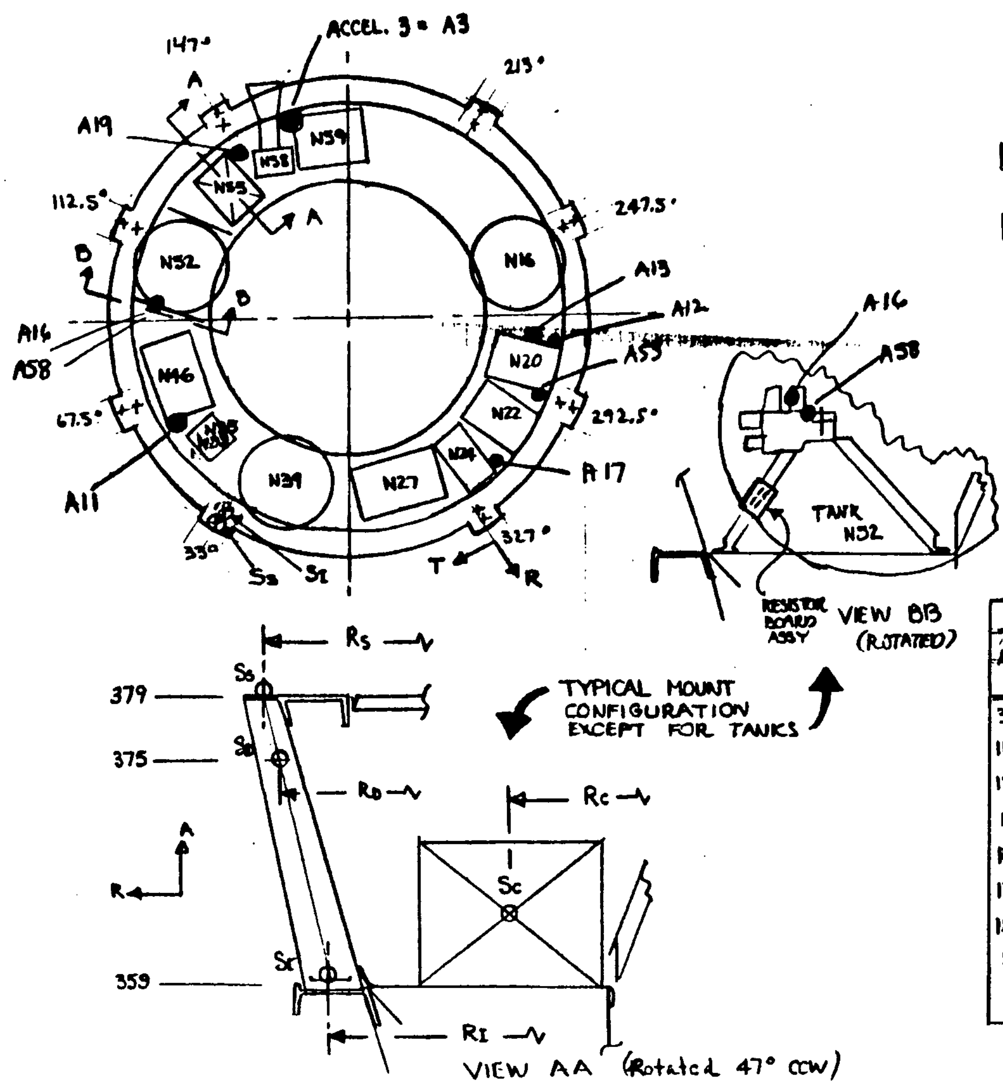


	COMPONENT		LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH / NUMBER OF JOINTS	
						SI – IUS			SD – S/C				
ID.	NAME		Xc	θc	Rc	XI	θI	RI	XD	θD	RD	I-C	D-C
N16	RCS TANK 3		368	253°	40	359	247.5	51	375	247.5	55	13/2	35/2
▷* N20	PDU (A)		359	285	42		292.5			292.5		11/1	27/1
N22	PDU (B)		359	304	42		292.5			292.5		14/1	30/1
▷* N24	PTU		359	320.5	40		327			327		13/1	29/1
N27	SCU (A)		359	344	39		327			327		19/1	35/1
N39	RCS TANK 2		368	23.5	40		33			33		12/2	28/2
▷* N46	SCU (B)		359	71.5	42		67.5			67.5		11/1	27/1
▷* N52	RCS TANK 1		368	107	40		112.5			112.5		20/2	36/2
▷* N55	PSU		359	137	40		147			147		15/1	31/1
N58	STAR SCANNER			157	44		147			147		11/1	27/1
▷* N59	RIMU			174	40		147			147		25/1	41/1
N83	TIU			45	42		33			33		15/1	31/1
N99	BATTERY			45	42		33			33		15/1	31/1

▷ QTV INSTRUMENTATION					▷ PATH LENGTH	
ACCEL	ID.	X_M	θ_M	R_M	I-M	D-M
3ART	N59	359	165	47	16/1	32/1
11ART	N46	380	61	48	8/2	24/2
12ART	▷N20+	360	277	46	18/2 ▷	34/2
13AR	N20	359	277	41	19/1	35/1
16ART	N52	371	90	44	23/4	39/4
17ART	N24	360	315	47	15/2	31/2
19ART	N55	360	143	44	8/2	24/2
55AR	▷N20+	360	293	48	10/2 ▷	26/2 ▷
58R	N52	370	92	42	22/3	38/3

A = Axial R = Radial T = Tangential

▷* Instrumentation on QTV
▷ On Component side of Isolators
▷ Shortest structural path from shock source to geometric center of component mount plane and number of joints in path
I-C Path from IUS Sep. Nut to component
D-C Path from S/C shock definition point to component
▷ Shortest structural path from shock source to acceleration measurement location and number of joints in path
I-M Path from IUS Sep. Nut to Accel.
D-M Path from S/C Shock definition point to Accel.

FIGURE 3.6.2
ESS DECK COMPONENTS
SHOCK PATHS

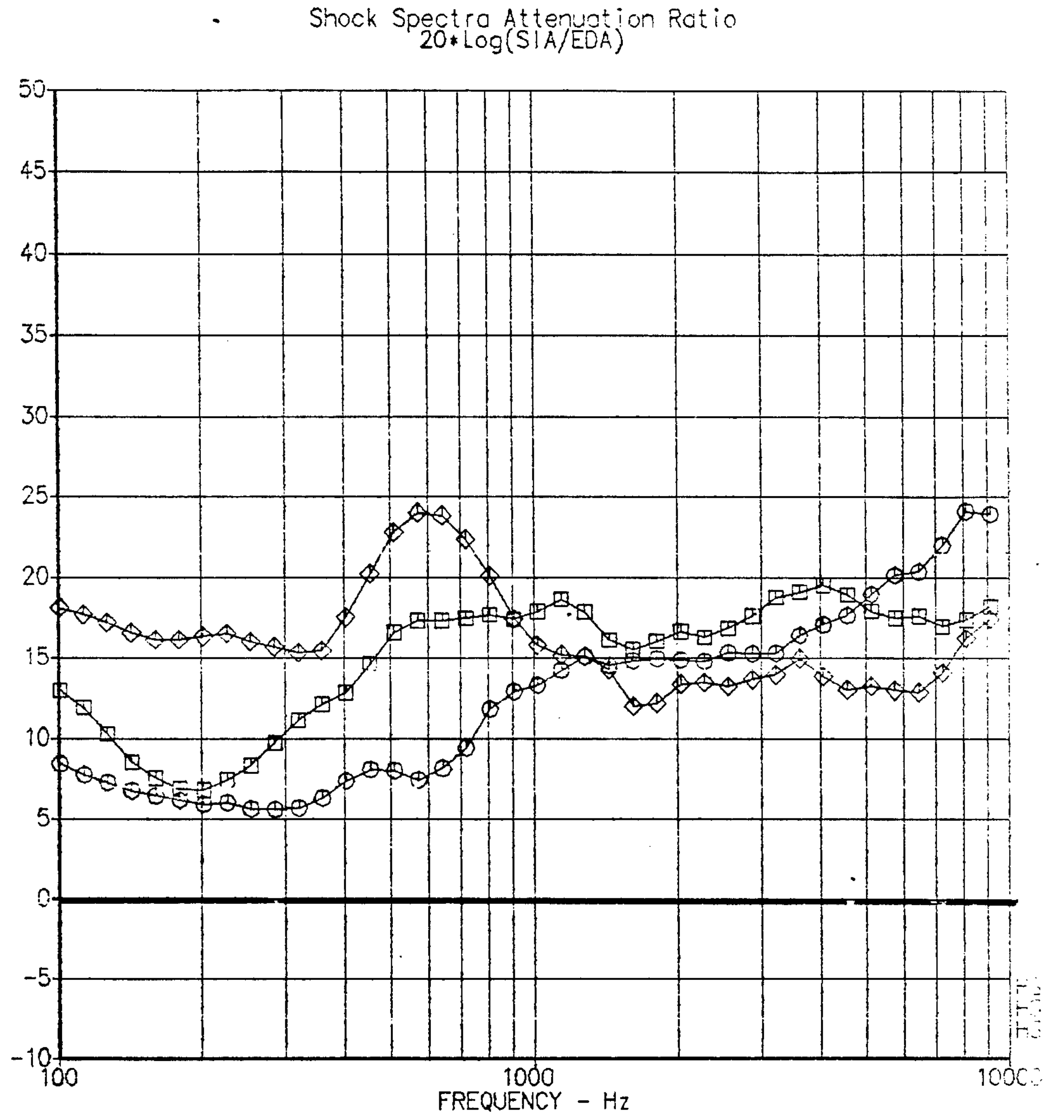
7/3c A 4/20/82

SHEET

D1 4802 8100 ORG 3/71

○ A12A (Axial)
□ A12R (Radial)
◇ A12T (Tangential)

A12



ATTENUATION A12
BETWEEN IUS SEP NUT AND ESS DECK

AXIAL
RADIAL
TANGENTIAL

CALC		9MAR82	REVISED	DATE	FIGURE 3.6.3	
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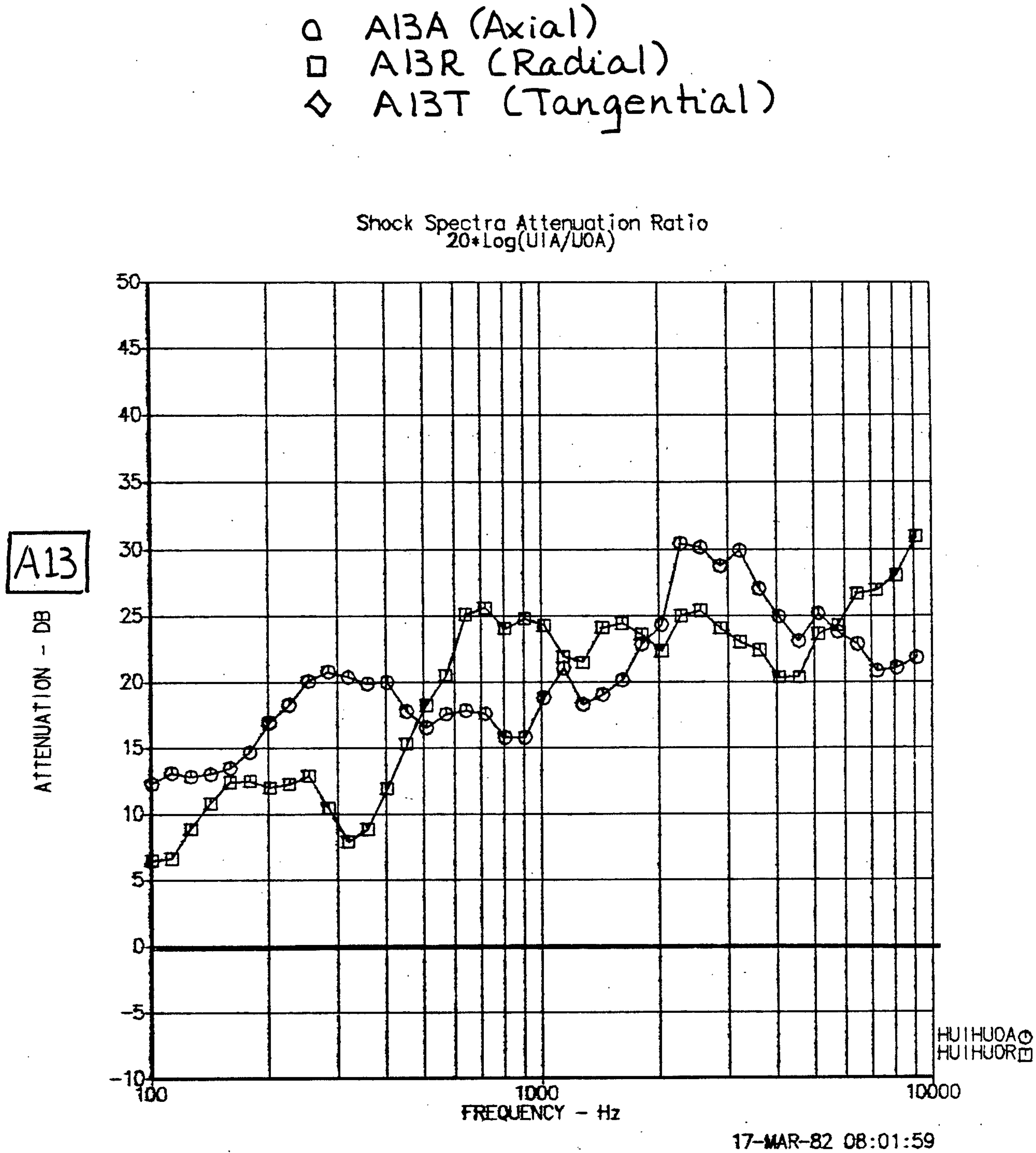
APPD.					THE BOEING COMPANY	PAGE B-50



ATTENUATION A13
ACROSS PDU ISOLATOR

CALC		17MAR82	REVISED	DATE	FIGURE 3.6.4	
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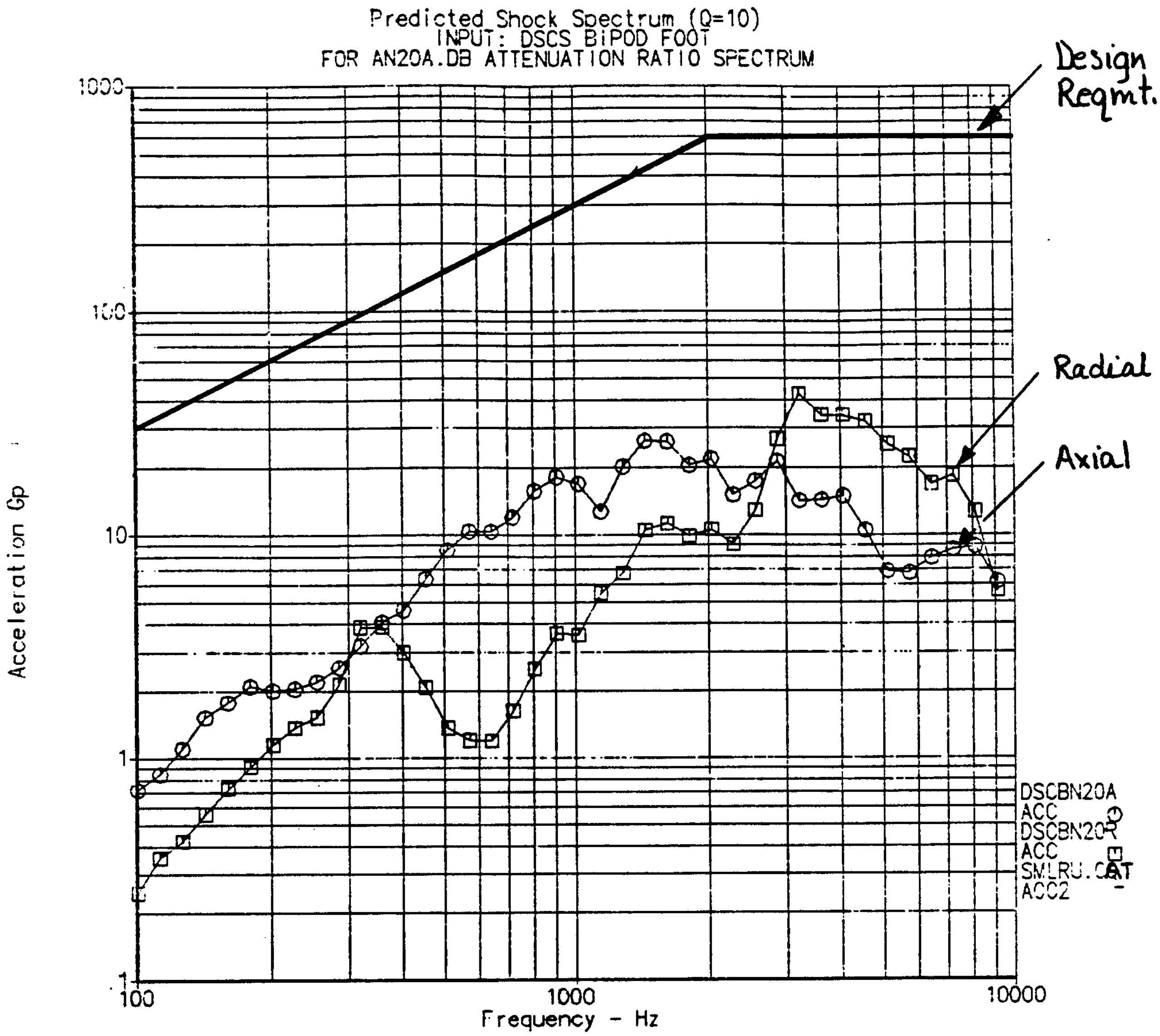

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PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT PDU LOCATION (ISOLATED SIDE)

AXIAL
RADIAL

CALC.	CB	23APR82	REVISED	DATE
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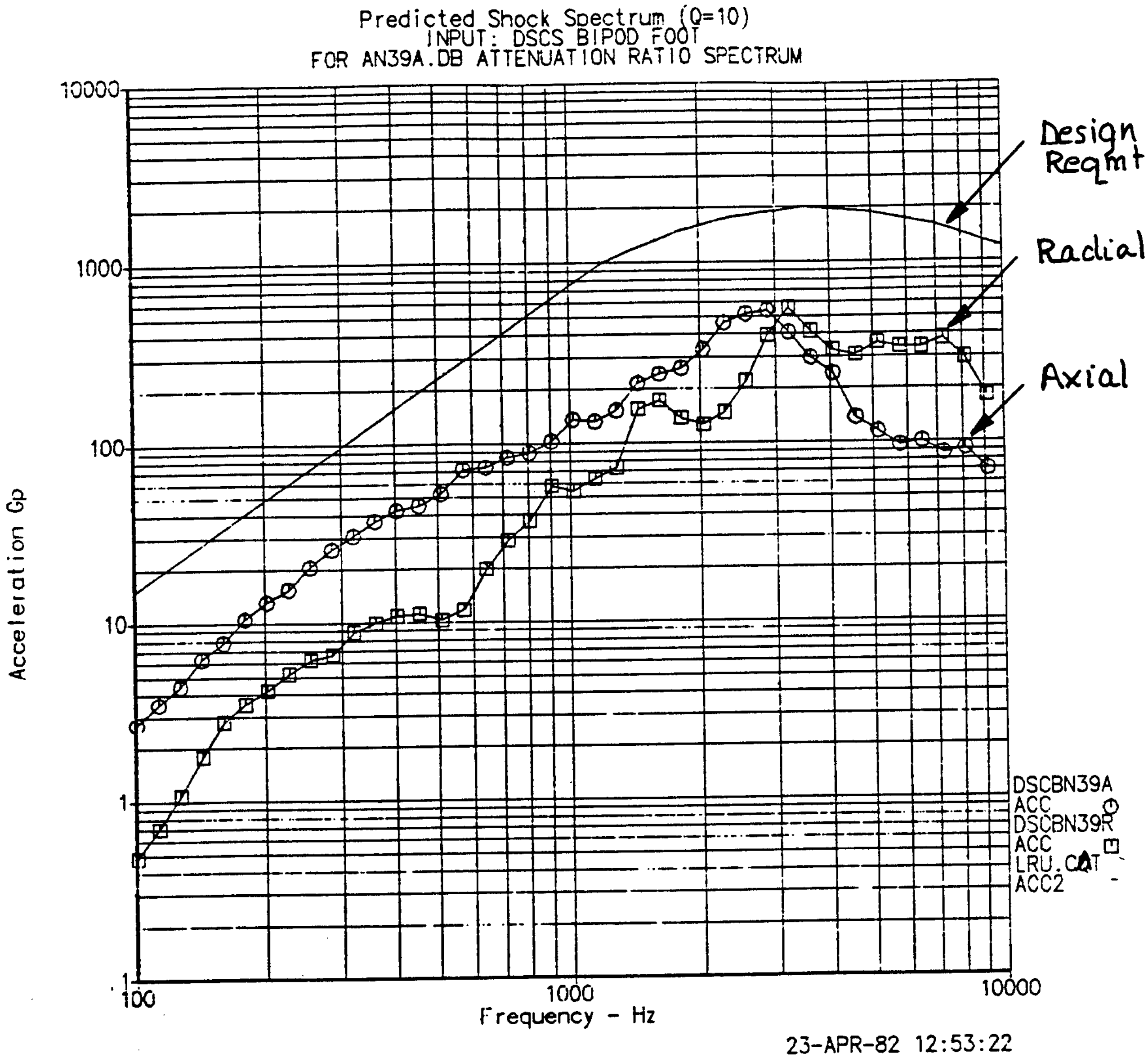
APPD.				

FIGURE 3.6.5



PREDICTED VS. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT RCS TANK LOCATION

AXIAL
RADIAL

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FIGURE 3.6.6

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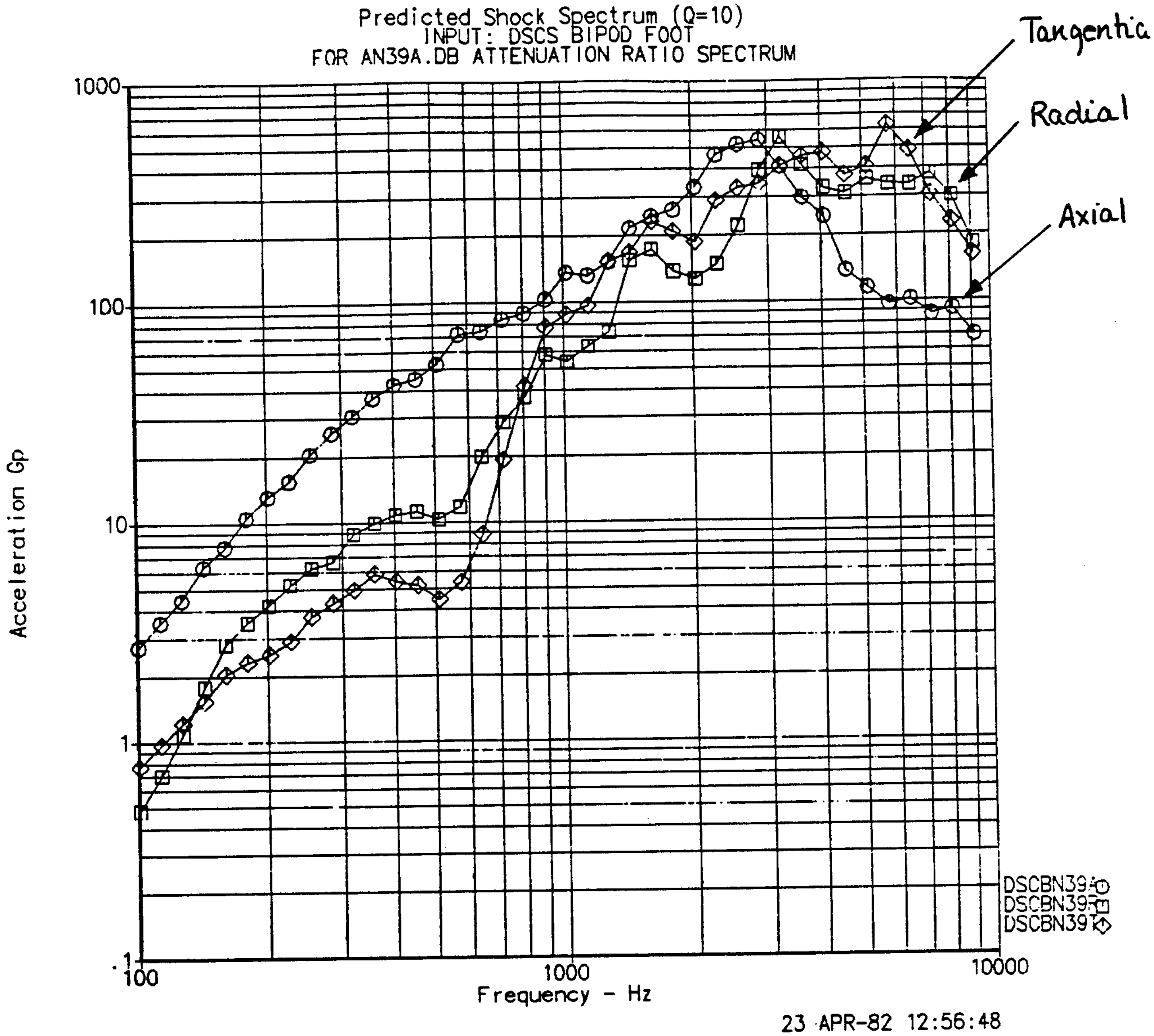

PREDICTED
DSCS INDUCED SHOCK
AT RCS TANK LOCATION

AXIAL
RADIAL
TANGENTIAL

CALC	CJS	23APR82	REVISED	DATE	FIGURE 3.6.7
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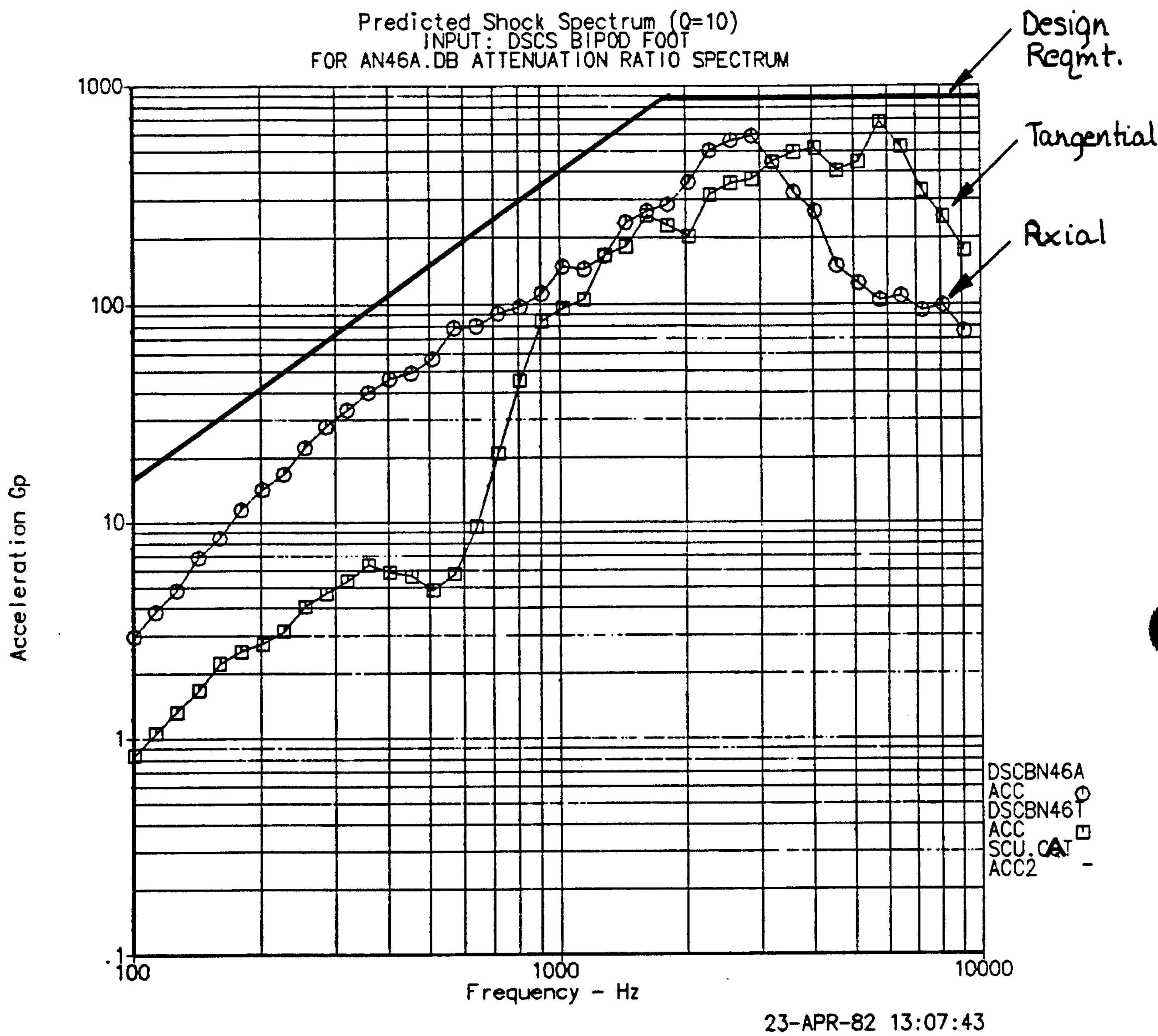

PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT SCU LOCATION

AXIAL
TANGENTIAL

CALC	ORS	23APR82	REVISED	DATE	FIGURE 3.6.8	
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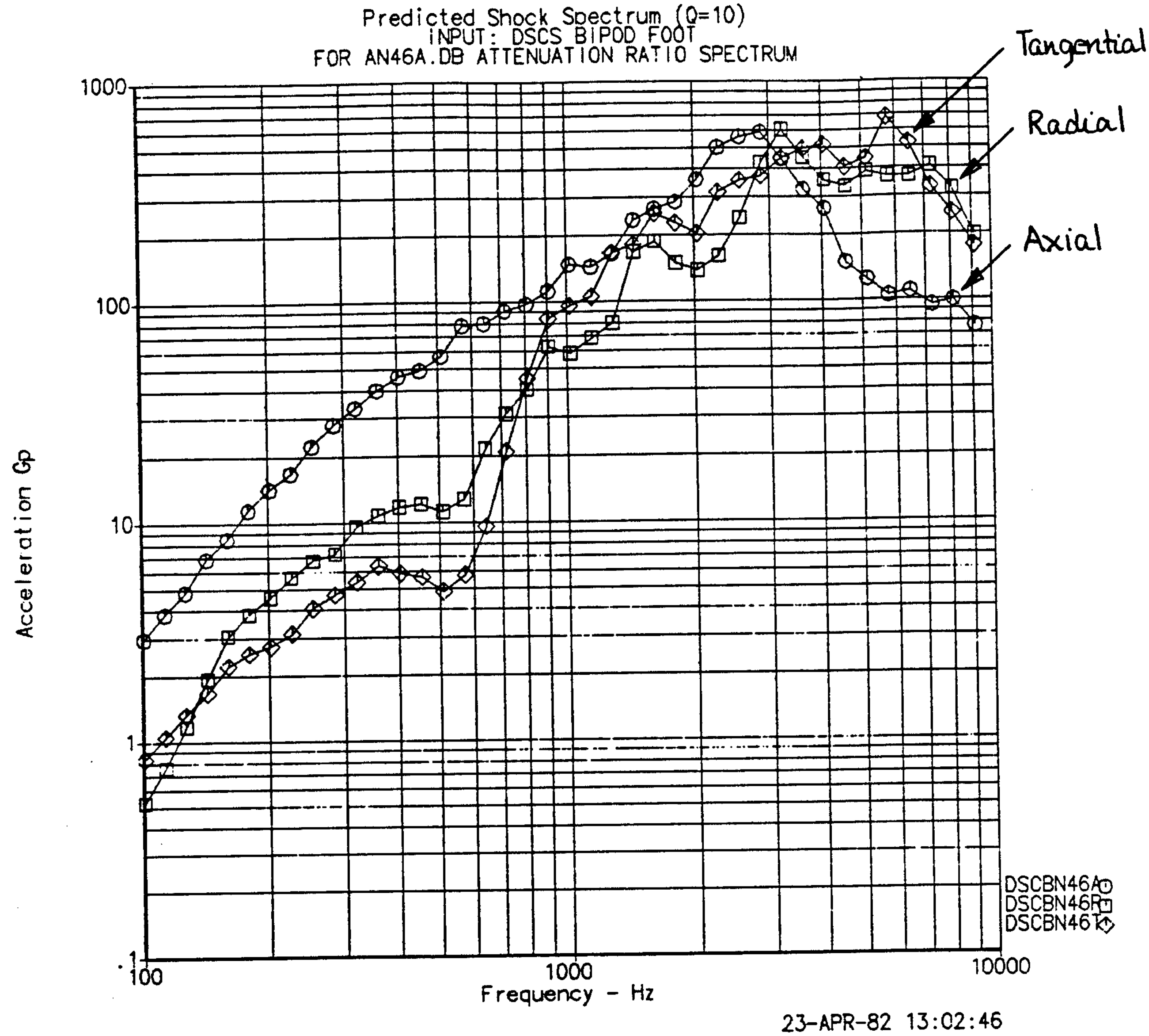
APPD.					THE BOEING COMPANY	PAGE B-55



PREDICTED
DSCS INDUCED SHOCK
AT SCU LOCATION

AXIAL
RADIAL
TANGENTIAL

CALC	CB	23APR82	REVISED	DATE	FIGURE 3.6.9	
CHECK						
APPD.						
APPD.					D290-75303-2 Vol. I A	PAGE B-56

3.7 Shock Prediction, RF Switch*, Fail Safe RF Relay*, Diplexer*

The equations and data used to predict the shock spectra for the RF Switch, RF Relay and Diplexer are shown on Figure 3.7.1. Equipment locations are shown on Figure 3.7.2. The predicted spectra are shown in Figures 3.7.4 through 3.7.7.

* RF Switch, BAC Drawing 280-41008;Fail Safe R/F Relay, BAC Drawing 280-41009;Diplexer, BAC Drawing 290-22200

GENERAL EQUATION SEE FIGURE 3.7.2

$Sc = Ss\,(10^{\frac{-A1-A14-AB}{20}})$

A1 = Attenuation across spacecraft/IUS joint, see Figs 3.1.3, 3.1.4, 3.1.5

A14 = Attenuation between spacecraft attach point and RF Switch / Diplexer support.

AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

APPLICABLE ACCELEROMETERS/EQUATIONS

See Figure 3.7.3

$$A14 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{cd})_f}$$

- Assumes S_I same for all longerons
- Shock path 40 in.

QTV ACCELS	
S_I	S_C
1 ART	44 ART
70 ART	

ID	S-C (Inches)	AB (db)	
N29A	37	-0.6	RF Switch
N31A	40	0	RF Switch
N33B	43	+0.7	RF Switch
N36B	46	+1.2	RF Switch
N34A	40	0	Diplexer
N35B	49	+1.8	Diplexer

$$AB = 20 \log \frac{S-C}{40}$$

S-C = Shock path length from spacecraft source to component.

FINAL EQUATIONS

$$S_{N29A} = S_s\,(10^{\frac{-A1-A14+0.6}{20}})$$

$$S_{N34A} = S_s\,(10^{\frac{-A1-A14}{20}})$$

Predicted shock spectra shown in Figures 3.7.4 thru 3.7.7.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

FIGURE 3.7.1
RF SWITCH / DIPLEXER
SHOCK EQUATIONS

C.J. Berk 4/26/82

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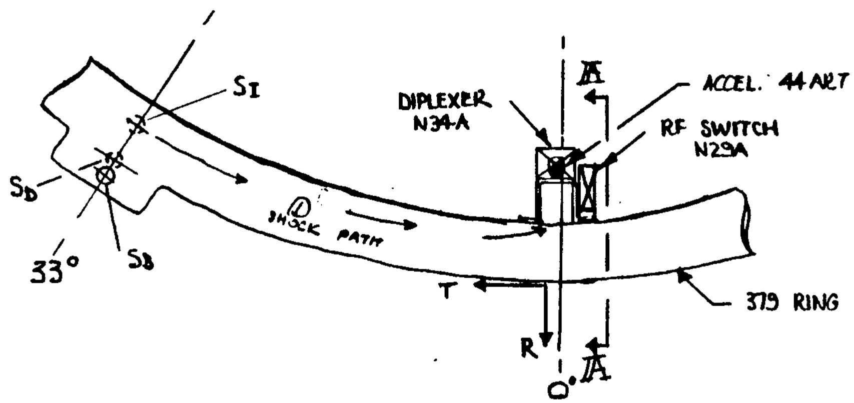
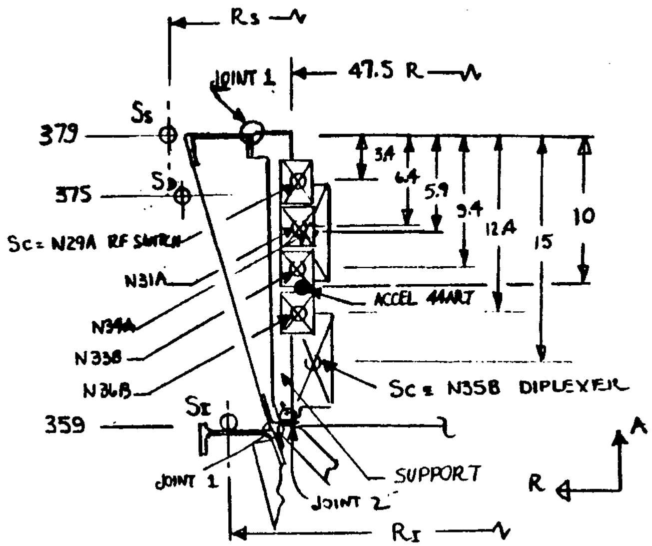
NUMBER
REV LTR





COMPONENT		LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH / NUMBER OF JOINTS [1]	
					S_I ~ IUS			S_S ~ S/C				
ID.	NAME	Xc	θc	Rc	XI	θI	RI	XS	θS	RS	I-C	S-C
N29A	RF SWITCH	376"	358°	47"	359"	33°	51"	379"	33°	56"	47/2	37/1
N31A		373									44/2	40/1
N33B		370									41/2	43/1
N36B		367									38/2	46/1
N34A	DIPLEXER UPPER	373	0°	46.5"							44/2	40/1
N35B	DIPLEXER LOWER	364	0°	46.5"							35/2	49/1

[1] SHOCK PATH CALCULATIONS

IUS SOURCE (S_I) TO NEAREST RF SWITCH (Sc = N36B) ( ) = I-C

① From 33° Nut (S_I) thru 359 Ring to 0° — 30"

② Thru Joint 1 to deck, thru Joint 2 into support, up support to N36b — 8"

SPACECRAFT SOURCE (S_S) TO NEAREST RF SWITCH (Sc = N29A) = S-C

① From Spacecraft Attach Point at 33° (S_S) thru 379 Ring to 0° — 32"

② Thru Joint 1 to Support, 1 down Support to N29A — 5"

QTV INSTRUMENTATION		
NO.	I-M	S-M
44 ART	40/2	44/1

I-M = Shortest path from S_I to Accel. (M)/No. of joints
S-M = Shortest path from S_S to Accel. (M)/No. of joints
A = Axial R = Radial
T = Tangential

FIGURE 3.7.2
RF SWITCH/DIPLEXER
SHOCK PATHS

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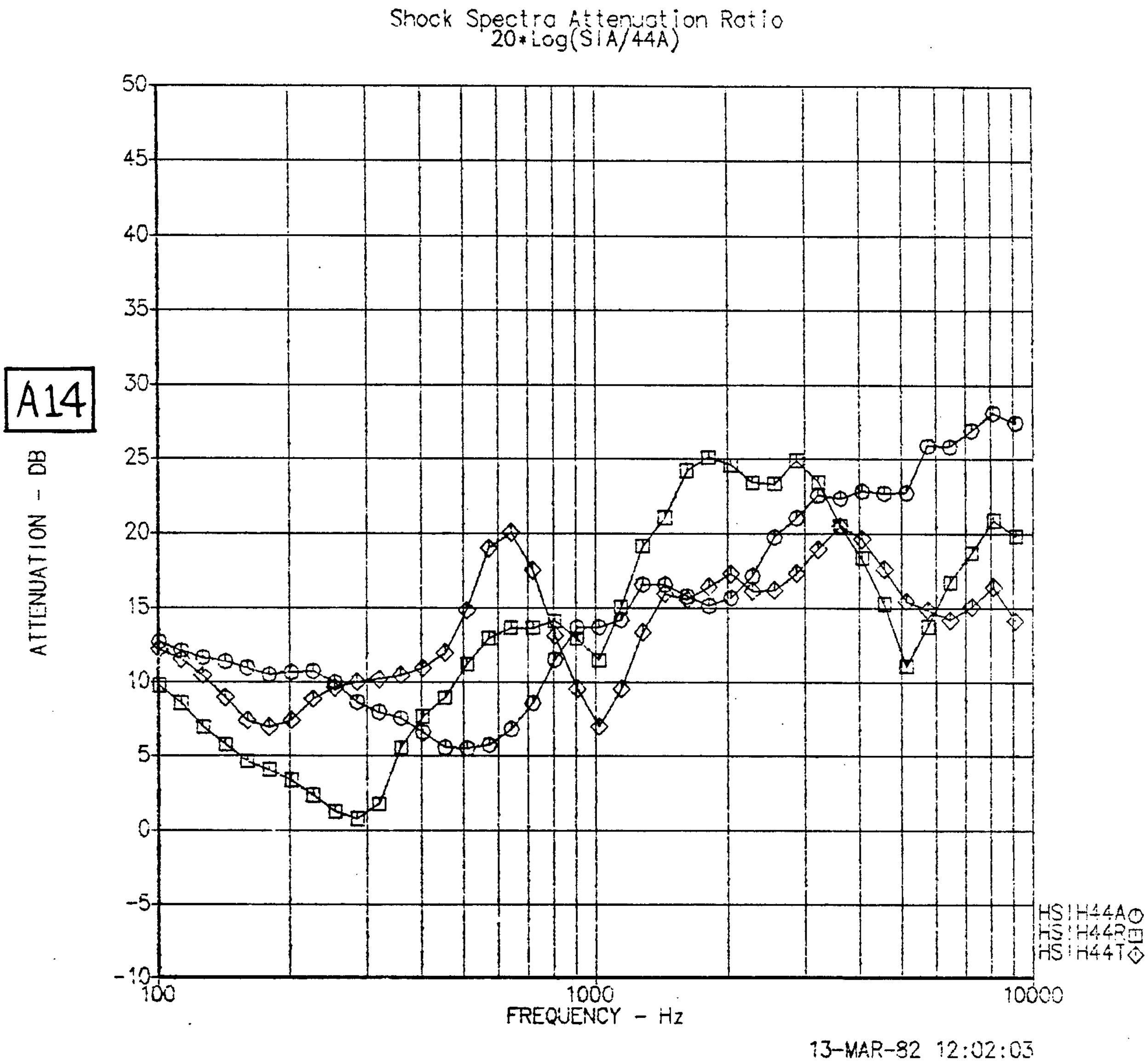
SHEET

O A14A (Axial)
□ A14R (Radial)
◇ A14T (Tangential)



ATTENUATION A14

BETWEEN SPACECRAFT ATTACH POINT AND RF/SWITCH / DIPLEXER SUPPORT

AXIAL
RADIAL
TANGENTIAL

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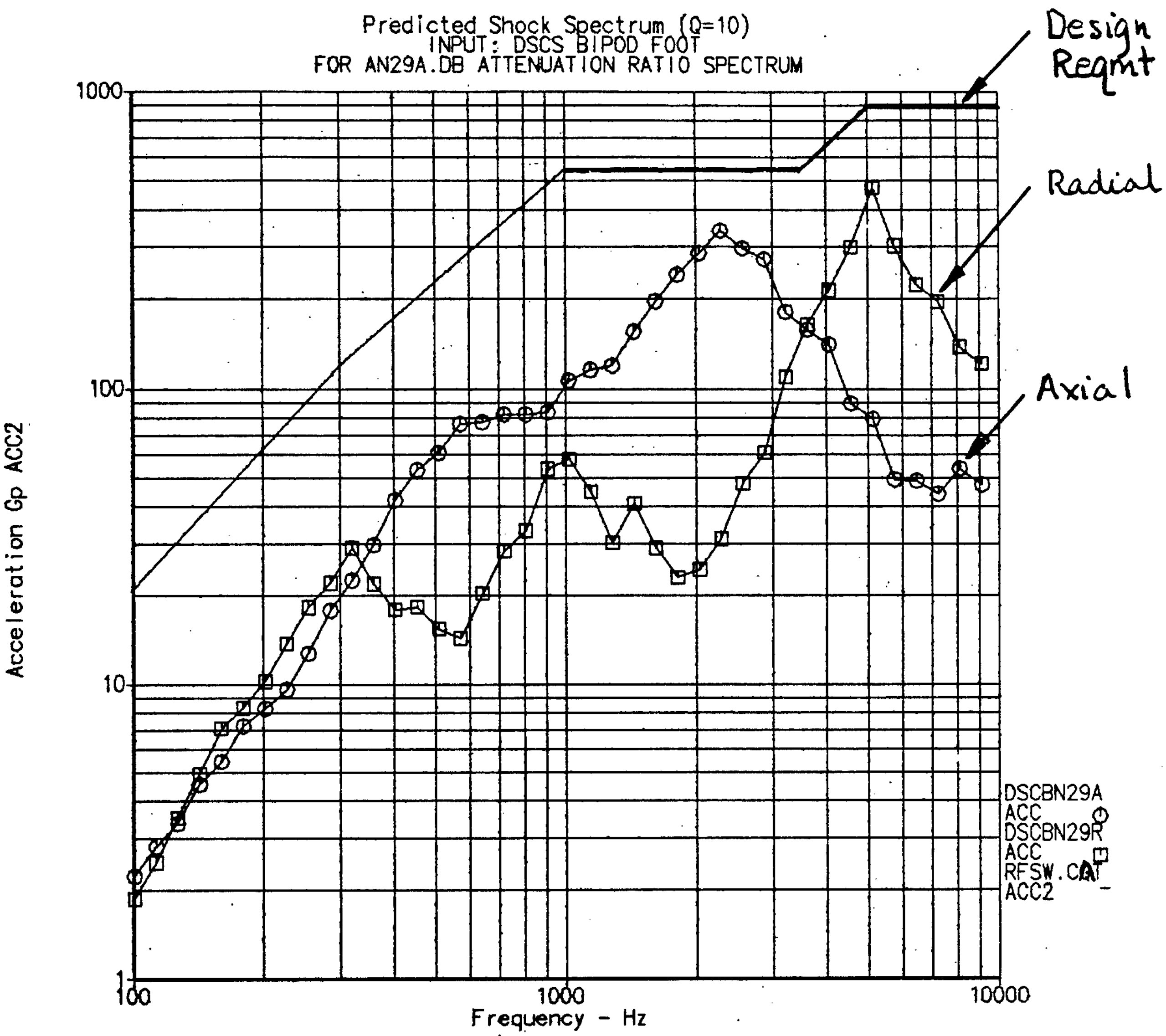

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PREDICTED VS. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT RF SWITCH LOCATION

AXIAL
RADIAL

CALC	DB	26APR82	REVISED	DATE	FIGURE 3.7.4	
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APPD.					THE BOEING COMPANY	PAGE B-61

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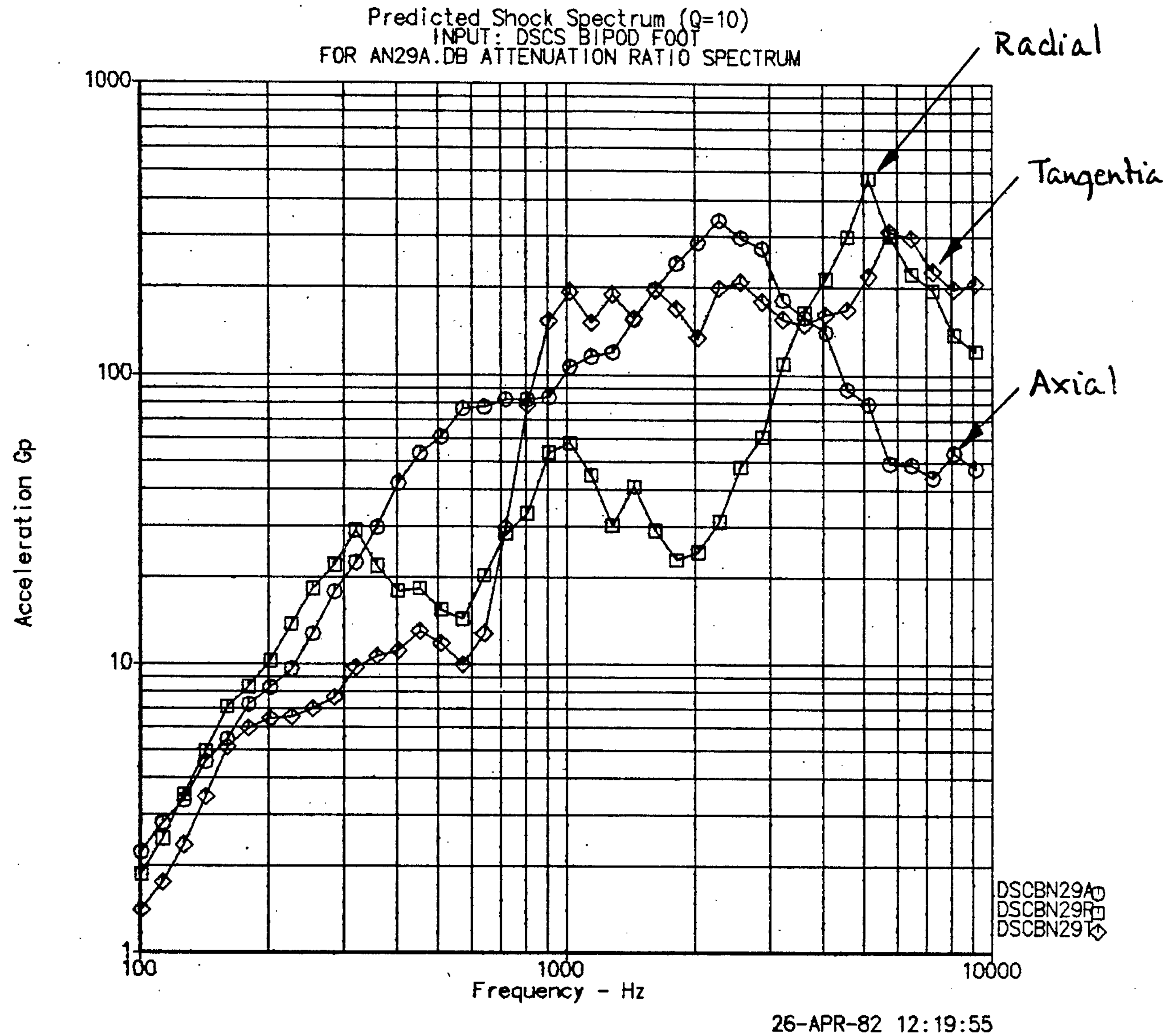

PREDICTED
DSCS INDUCED SHOCK
AT RF SWITCH LOCATION

AXIAL
RADIAL
TANGENTIAL

CALC	CJS	26APR82	REVISED	DATE	FIGURE 3.7.5	
CHECK						
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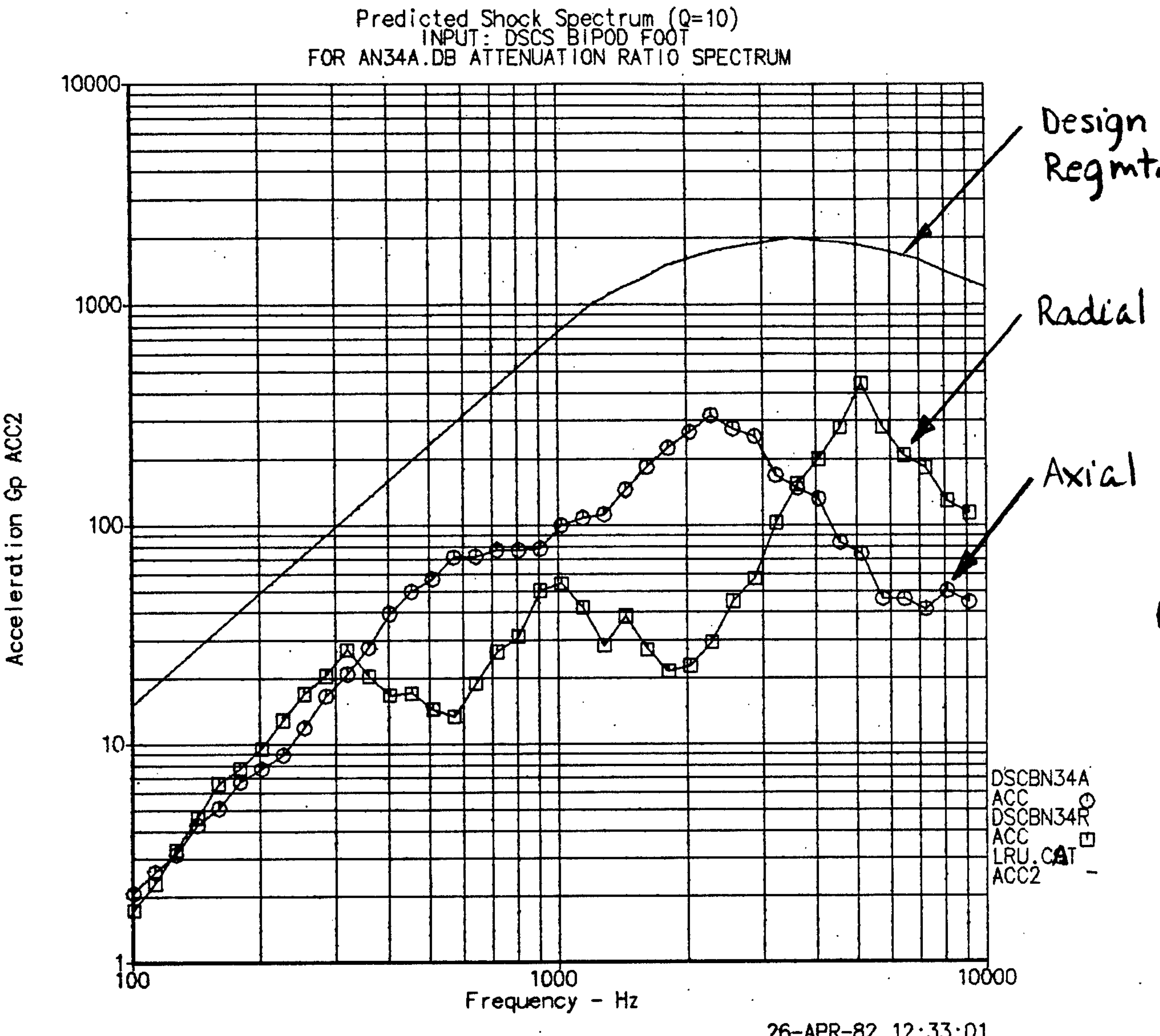

PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT DIPLEXER LOCATION

AXIAL
RADIAL

CALC	CB	26APR82	REVISED	DATE	FIGURE 3.7.6	
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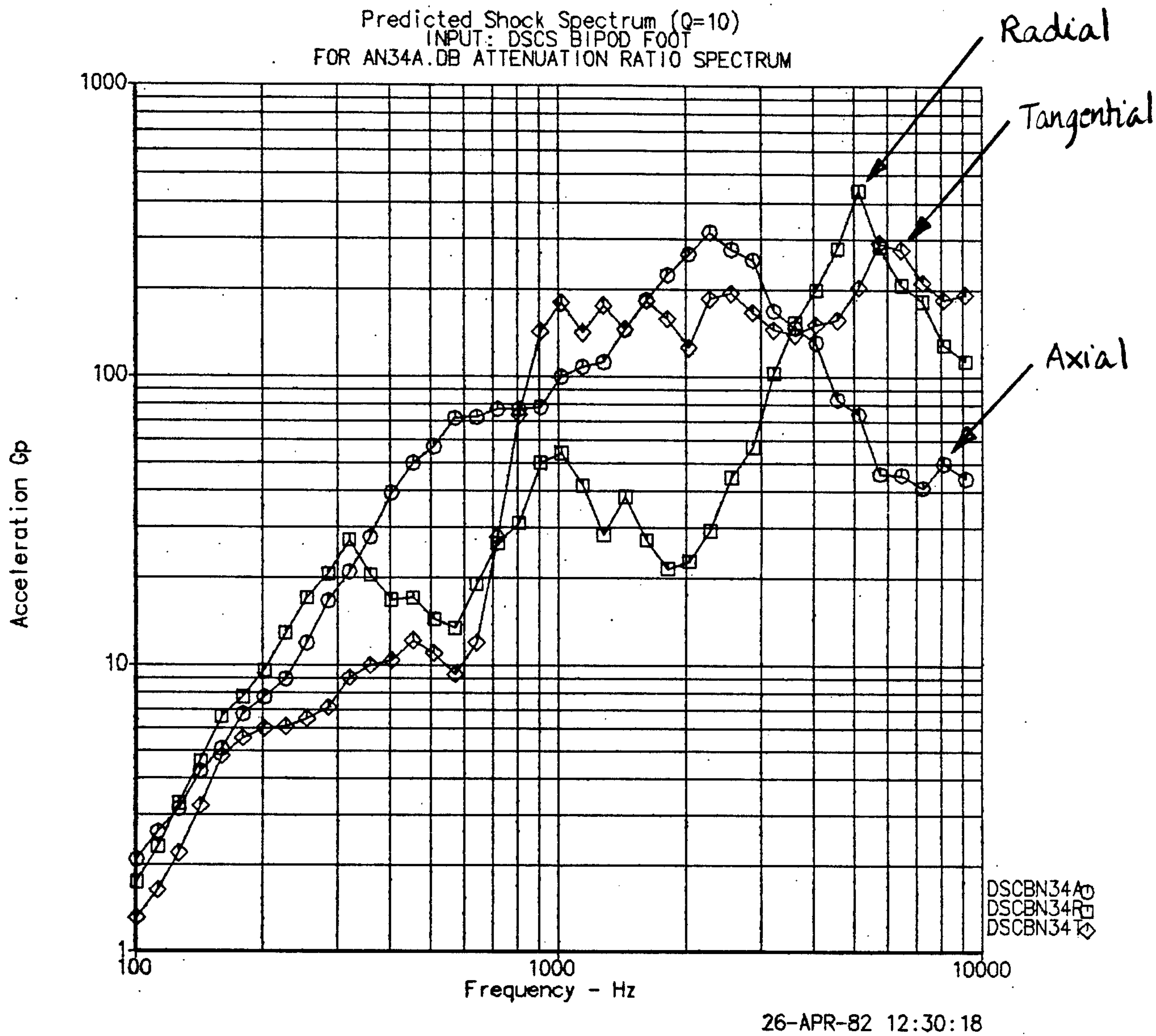

PREDICTED
DSCS INDUCED SHOCK
AT DIPLEXER LOCATION

AXIAL
RADIAL
TANGENTIAL

CALC	QB	26APR82	REVISED	DATE	FIGURE 3.7.7	
CHECK						
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3.8 Shock Prediction, Medium Gain Antenna*, EMU Transducers*

The equations and data used to predict the shock spectra for the Medium Gain Antenna and EMU Transducers are shown on Figure 3.8.1. Equipment locations are shown on Figure 3.8.2. Only the EMU Shock Transducers are considered for this analysis since the EMU Vibration Transducers are not required to function at the time of spacecraft separation. The predicted spectra are shown in Figures 3.8.4 and 3.8.5.

BOEING

NUMBER
REV LTR

GENERAL EQUATION

SEE FIGURE 3.8.2

$S_c = S_s \left(10^{\frac{-A1-A15-AB}{20}}\right)$ Antennas N78 & N80 — $S_c = S_s$ - Shock Accels N86, N87

A1 = Attenuation across spacecraft/IUS joint, see Figures 3.1.3, 3.1.4, 3.1.5.

A15 = Attenuation between spacecraft attach point and Antenna N78 location.

AB = Attenuation correction for distance.

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.8.3

$$A15 = 20 \log \frac{(\bar{S}_{65d})_f}{(\bar{S}_{09d})_f}$$

Shock path = 16 in.

$$AB = 20 \log \frac{S-C}{16}$$

QTV ACCELS	
65A,R	09A,R

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface). See Figure 1.

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at the eight Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

B = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

FINAL EQUATIONS

$S_{N78} = S_s \left(10^{-\frac{A1-A15}{20}}\right)$ See Figure 3.8.4

$S_{N80} = S_s \left(10^{-\frac{A1-A15-2B}{20}}\right)$

$S_{N86} = S_{N87} = S_s$ See Figure 3.8.5

FIGURE 3.8.1
ANTENNA AND
EMU SHOCK ACCELEROMETER
SHOCK EQUATIONS

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SHEET

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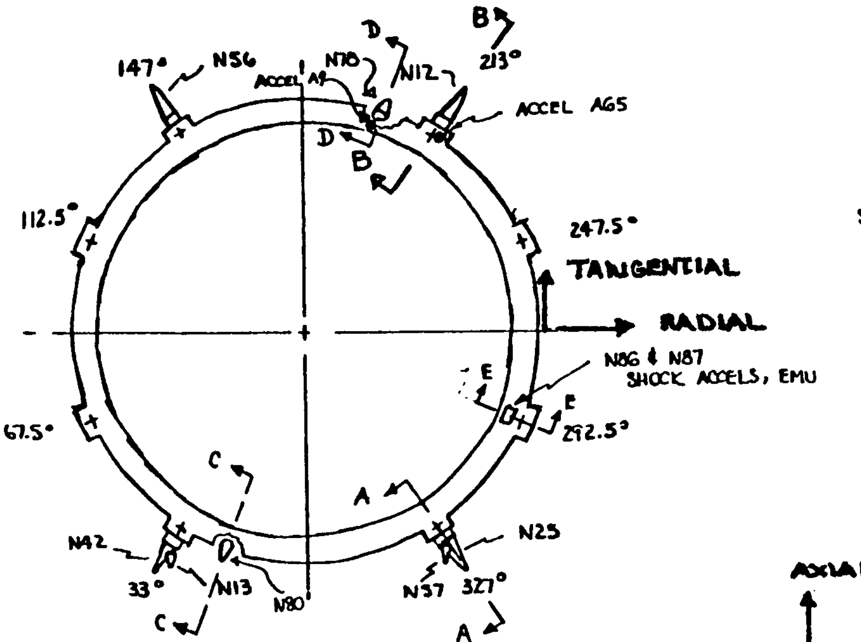

	ID.	COMPONENT NAME	LOCATION X_C	LOCATION Θ_C	LOCATION R_C	SOURCE NEAREST COMPONENT S_I ~ IUS X_I	S_I ~ IUS Θ_I	S_I ~ IUS R_I	S_D ~ S/C X_D	S_D ~ S/C Θ_D	S_D ~ S/C R_D	PATH LENGTH / NUMBER OF JOINTS I-C	S-C
STS	N12	OMNI ANTENNA	370"	213°	60"	359"	213°	51	379"	213°	55"	17"/1	
	N13	MED. GAIN ANT.	375	33	60	↓	33	↓	↓	33	↓	21"/1	
	N25	OMNI ANT.	370	327	60"	↓	327	↓	↓	327	↓	17/1	
	N42	OMNI ANT.	370	33°	60	↓	33	↓	↓	33	↓	17/1	
	N56	OMNI ANT.	370	147°	60	↓	147	↓	↓	147	↓	17/1	
	N57	MED. GAIN ANT.	375	327	60	↓	327	↓	↓	327	↓	21/1	
T34D	N78	MED. GAIN ANT.	375	200	50	↓	213	↓	↓	213	↓	37/1	16/1
	N80	MED. GAIN ANT.	369	20	50	↓	33°	↓	↓	33	↓	42/1	22/1
	N86	SHOCK ACCEL.	379	292.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1
	N87	SHOCK ACCEL	379	292.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1

I-C = Shock path length from IUS Separation Nut to Component

S-C = Shock path length from Spacecraft Attach point to Component

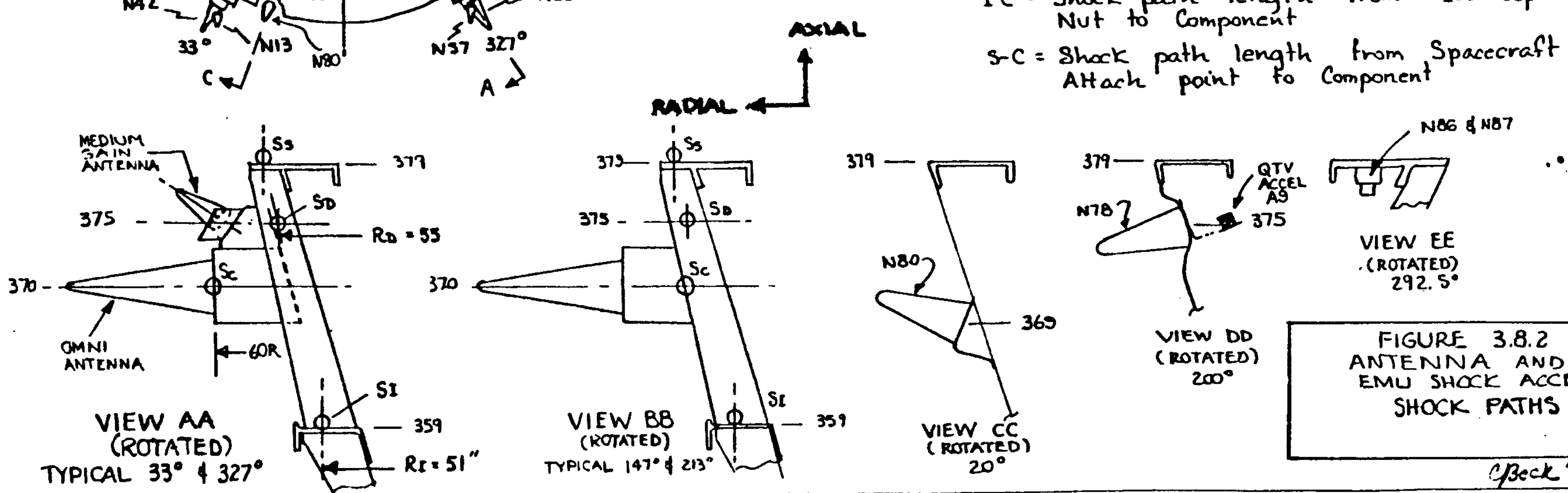

FIGURE 3.8.2
ANTENNA AND
EMU SHOCK ACCELS
SHOCK PATHS

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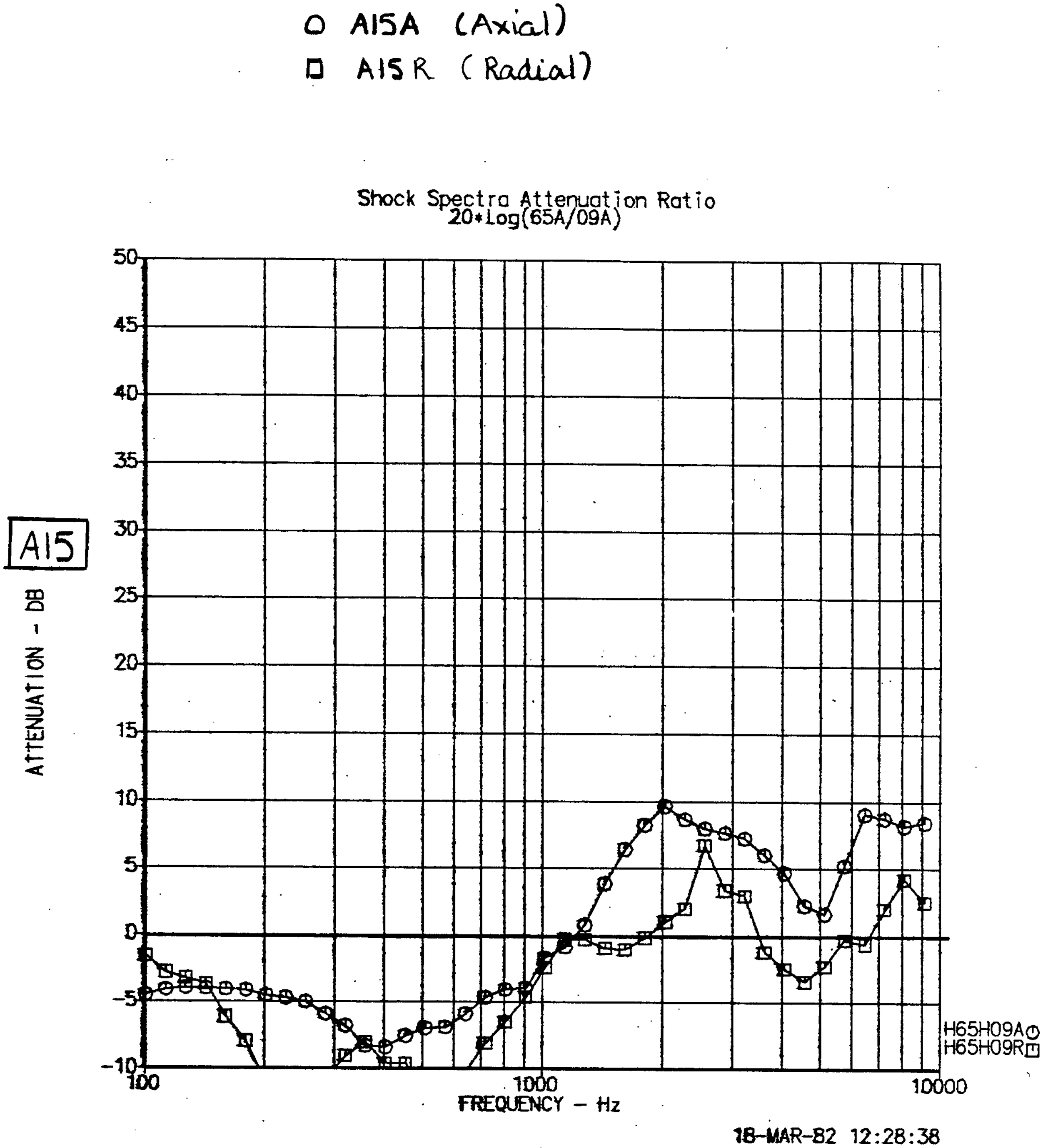

ATTENUATION A15
BETWEEN SPACECRAFT ATTACH POINT
AND MEDIUM GAIN ANTENNA N78

AXIAL
RADIAL

CALC	C/S	18MAR82	REVISED	DATE	FIGURE 3.8.3	
CHECK						
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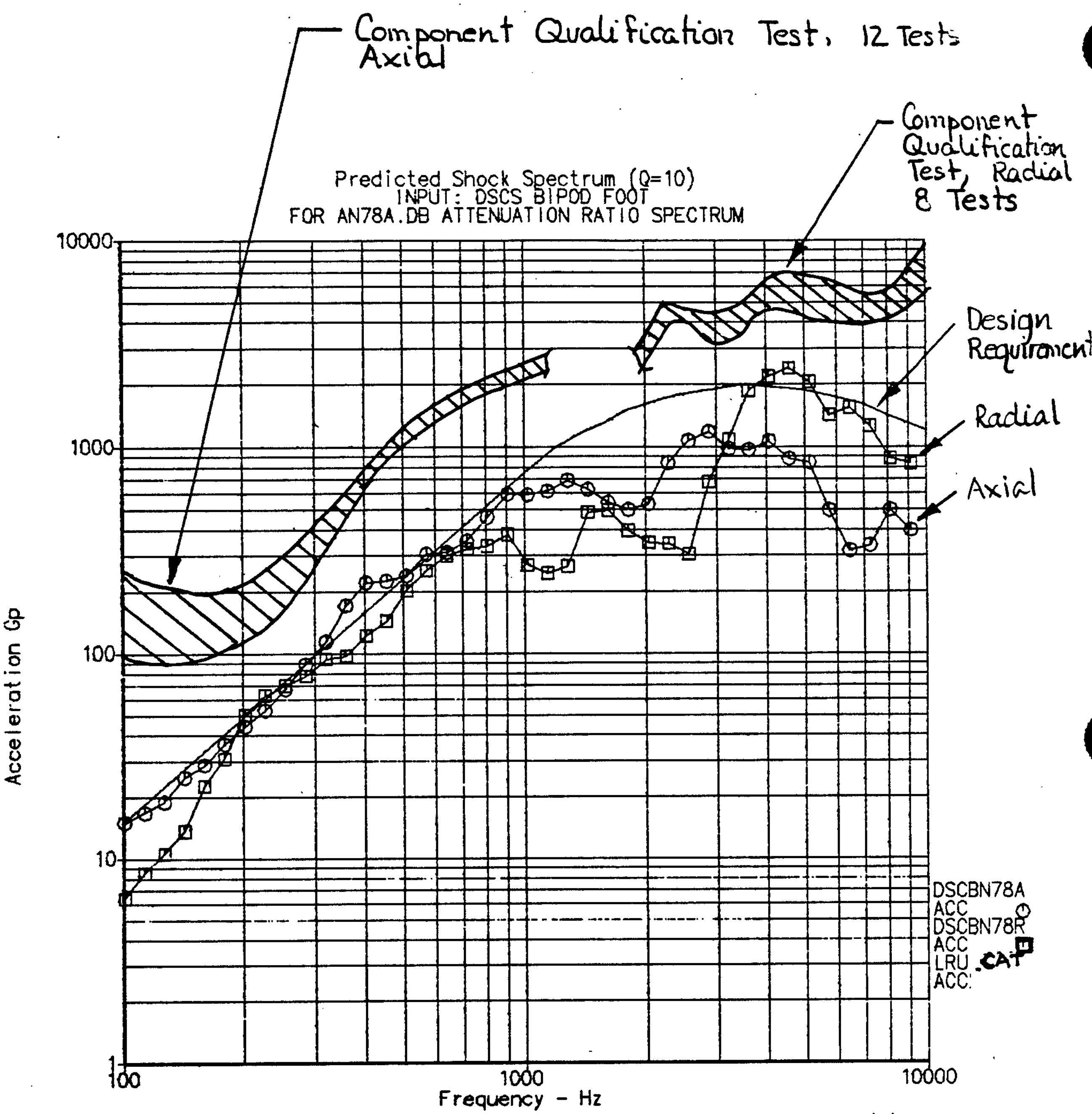
APPD.						



PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT MEDIUM GAIN ANTENNA N78

AXIAL
RADIAL

CALC	CJs	26APR82	REVISED	DATE	FIGURE 3.8.4	
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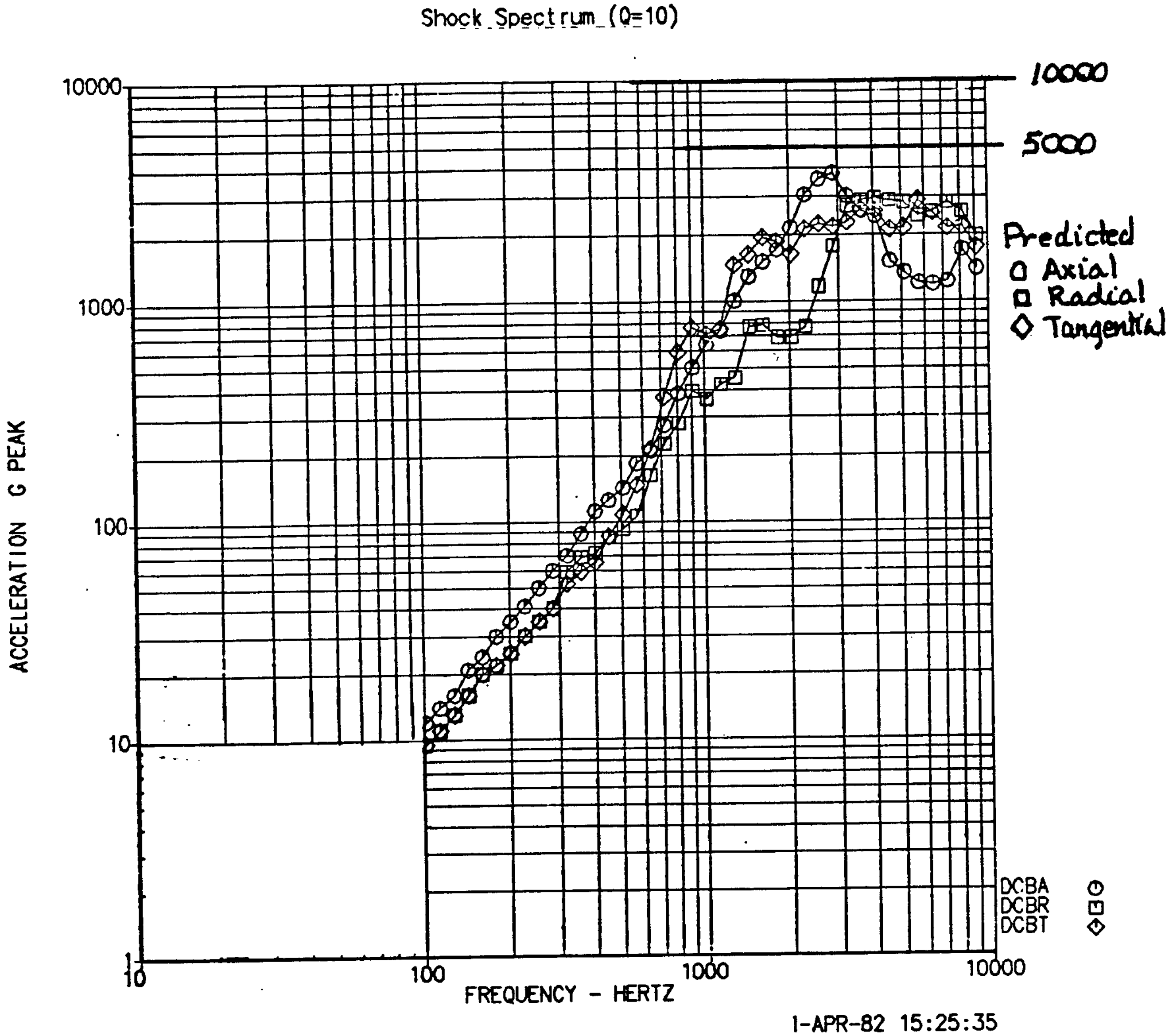
APPD.					THE BOEING COMPANY	PAGE B-69

Design Requirement
± 10000 g in accelerometer sensitive axis
± 5000 g in accelerometer transverse axes



PREDICTED vs. DESIGN REQUIREMENT
DSCS INDUCED SHOCK
AT EMU SHOCK ACCELEROMETER LOCATIONS

CALC	CB	1APR82	REVISED	DATE	FIGURE 3.8.5
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4.0 CONCLUSIONS

The IUS components are compatible with the DSCS III induced shock. The rationale for this conclusion follows.

1. Predicted IUS component shock environments due to DSCS III induced shock are less than component design requirements except for REM, Computer and Antenna.

2. The REM is compatible with the DSCS induced environment since the REM component qualification test levels are 6 db greater than the prediction except for the frequency range between 1000 and 2000 Hz, Figure 3.1.9. The REM is not susceptible to shock in this frequency range. The REM is mounted on vibration isolators. The isolators eliminate vibration induced valve chatter at 240 Hz and 540 Hz. The radial axis is critical for valve chatter.

3. The Computer is compatible with the DSCS induced environment because the Computer component qualification test levels are 6 db greater than the prediction, Figure 3.2.5.

4. The Antenna is compatible with the DSCS induced shock because the Antenna component qualification levels are 6 db greater than the predicted environment, Figure 3.8.4. Also the Antenna is a simple device with no moving parts. MIL-STD-1540A, Table II, states that pyro shock tests for antennas is optional.

Appendix C

Evaluation of IUS Equipment Compatibility with Spacecraft Generated Shock

14 February 1983

Prepared by
Clark Beck

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SUMMARY

This document contains an evaluation of the compatibility of IUS components with pyrotechnic shock environments generated onboard a spacecraft attached to IUS. Figure 1 lists the components evaluated. The spacecraft shock environment is specified in the IUS Prime Item Development Specification (PIDS). The environment is defined as a shock spectrum with the peak level of 7500 gs Hz occurring on the IUS 4 inches from the IUS/spacecraft interface.

Thirty-five of the 45 components evaluated have been qualification tested to a level 6 db greater than the calculated component response to the spacecraft generated shock.

Ten of the components have not been qualified to the spacecraft generated shock level plus 6db by test. These 10 components are:

1. *Computer*
2. *SCU*
3. *RF Switch*
4. *Fail Safe RF Relay*
5. *Omni Antenna*
6. *Med. Gain Antenna*
7. *Diplexer*
8. *EMU Transducer*
9. *Temperature Sensor*
10. *Separation Nut*

Eight of the 10 components can be qualified by analysis. The analysis is part of this report.

Two components require additional qualification testing to demonstrate compatibility with the spacecraft separation shock. These components are:

RF Switch
Fail Safe RF Relay

The qualification levels are included in this document.

FIGURE 1 IUS COMPONENTS/COMPATIBILITY

COMPONENT	BAC DWG/CI	FUNCTION	COMPATIBILITY
Safe & Arm, SRM-1 (Stage 1)	290-21005/CI290014A	B	C Section 4
Safe & Arm, SRM-2	290-21005/CI290014A	B	C Figure 4-1
REM	290-21002/CI290020A	A	C Figure 4-2
RCS Manifold	290-21031/CI290071A	A	C Section 4
RCS Tank Module Assy	290-21007/CI290072A	A	C Figure 4-3
Resistor Board Assy	290-21066/CI290A30A	A	C Figure 4-4
Star Scanner	290-22127/CI290039A	B	C Figure 4-5
Inertial Meas. Unit	290-22118/CI290024A	A	C Figure 4-6
TVC Actuator	290-22116/CI290015A	B	C Figure 4-7
TVC Controller	290-22116/CI290015A	B	C Figure 4-8
TVC Potentiometer	290-22116/CI290015A	B	C Figure 4-7
Computer, Central Avion.	290-22119/CI290025A	A	N Figure 4-9
Signal Cond. Unit (SCU) and Code Plug, SCU	290-26016/CI290016A	A	N Figure 4-10
Signal Interface Unit (SIU)	290-26199/CI290199A	A	C Figure 4-11
Titan Interface Unit (TIU)	290-26197/CI290197A	B	C Figure 4-12
RF Switch (2 pole)	280-41008	A	N Figure 4-13

Notes
A Component function required during or after spacecraft separation.
B Component function not required during or after spacecraft separation.
C Component compatible with spacecraft shock.
N Component qualification level is not 6 db greater than calculated shock.

FIGURE 1 IUS COMPONENTS/COMPATIBILITY

COMPONENT	BAC DWG/CI	FUNCTION	COMPATIBILITY
Antenna, Omni, DOD	290-27105	A	N Figure 4-14
Antenna, Med. Gain	290-27106	A	N Figures 4-15,4-16
SGLS Transponder, S Band	290-22121/CI290018A	A	C Figure 4-17
20 Watt Amplifier, S Band	290-22117/CI290021A	A	C Figure 4-18
Diplexer (DOD)	290-22200	A	N Figure 4-19
Environ. Meas. Subsystem	290-22224	A	C Figure 4-20
EMU Transducers	290-22228	A	N Figure 4-21
Fail Safe R/F Relay	280-41009	A	N Figure 4-13
DC Block (Stage 1)	280-61001	B	C Section 4
Avionics Battery (140 AH) (Stage 1)	290-22211/CI290023A	B	C Section 4
Utility Battery (13 AH)	290-22212/CI290037A	A	C Figure 4-22
Avionics/Spacecraft Battery (100 AH) (Stage 1)	290-22211/CI290037A	B	C Section 4
Avionics Battery (170 AH, Stage 1)	290-22211/CI290023A	B	C Section 4
T34D/IUS Destruct Battery	290-27001	B	C Section 4
DC/DC Converter Regulator	290-22210/CI290038A	B	C Figure 4-23
Pyro Switching Unit (PSU)	290-26054/CI290054A	B	C Figure 4-24
Power Transfer Unit (PTU)	290-27200/CI290056A	B	C Figure 4-25

Notes
A Component function required during or after spacecraft separation.
B Component function not required during or after spacecraft separation.
C Component compatible with spacecraft shock.
N Component qualification level is not 6 db greater than calculated shock.

FIGURE 1 IUS COMPONENTS /COMPATIBILITY

COMPONENT	BAC DWG/CI	FUNCTION	COMPATIBILITY
Power Distributor Unit (PDU)	290-26117/CI290017A	A	C Figure 4-26
Isolation Diode Assy	290-26070	B	C Figure 4-27
Temperature Sensor Assy	290-26222	B	N Figure 4-28
Separation Nuts	290-24130/CI290019A	B	N Figure 4-29
Staging Mech. (Super Zip, Stage 1)	290-24006/CI290053A	B	C Section 4
T34D/IUS Destruct System	290-24172/CI290093A	B	C Section 4
T34D/IUS Safe and Arm	290-21005/CI290014A	B	C Section 4
Encryptor (KG-46)	290-24109	A	C Figure 4-30
Decryptor (KIR-23)	290-24109	A	C Figure 4-31
EEC		B	C Section 4
Staging Connector	280-33019	B	C Figure 4-32
Pyro Connector (Stage 1)	280-33019	B	C Section 4

Notes
A Component function required during or after spacecraft separation.
B Component function <u>not</u> required during or after spacecraft separation.
C Component compatible with spacecraft shock.
N Component qualification level is not 6 db greater than calculated shock.

1.0 INTRODUCTION

Purpose

The purpose of this report is to present an evaluation of IUS equipment compatibility with pyrotechnic shock environments generated onboard a spacecraft attached to IUS.

Scope

The spacecraft induced shock design requirement is defined in section 2. The derivation of the design requirement is discussed and comparisons are made with IUS component design requirements and shock data measured on the IUS Qualification Test Vehicle (QTV). Section 3 presents the IUS components analyzed and describes the shock prediction method. The compatibility evaluation criteria and the evaluation results are presented in section 4. Conclusions and recommendations from this evaluation are shown in section 5. Section 5 also includes qualification analyses and qualification test levels for the RF Switch and the Fail Safe RF Relay. Section 6 presents a discussion of the transfer functions used to calculate the spacecraft generated shock.

2.0 DESIGN REQUIREMENT/BACKGROUND

Prime Item Development Spec (PIDS)

The spacecraft generated shock is defined in the IUS Prime Item Development Specification, S290-70001A, reference 1. The PIDS shock is shown in figure 2-1.

PIDS Background

The shock spectrum shown in figure 2-1 was derived from IUS Dynamic Test Vehicle (DTV) shock data, reference 2. The spectrum is an envelope of shock spectra caused by firing the IUS stage 1/2 separation nuts. The shock was measured at IUS station 362.5, this location is 3.5 inches from the separation nuts. Boeing recommended that the envelope be used to represent the shock response spectra at the spacecraft interface due to spacecraft disturbances, reference 3. However when the PIDS was released the following note was added: "Measured 4 inches on IUS side of interface." The "4 inch" note is thought to come from the Titan Transtage shock testing. Accelerometers were located 4 inches from the Transtage/spacecraft interface on the Transtage side to monitor shocks from the spacecraft.

IUS Component Design Requirement

Most IUS stage 2 equipment was designed for the environment shown in figure 2-2., curve 2. Curve 2 is an envelope of shock spectra measured at equipment attach points on the IUS DTV during stage 1/2 separation tests, reference 2. Reference 4 contains a discussion of the derivation of curve 2.

IUS Test Data

The IUS stage 1/2 separation shock environment at the spacecraft interface ring (IUS station 379) is shown in figure 2-2, curve 3. Curve 3 was derived from shock data measured on the IUS QTV, reference 5. There was no load on the IUS QTV spacecraft interface ring during the shock test.

Separation/shock tests have not been conducted with an IUS/spacecraft configuration to measure the response of IUS equipment to spacecraft generated shock. There have been no IUS shocks measured 4 inches on the IUS side of the interface.

3.2.5.5.2 Shock. The shock environment at the IUS vehicle/spacecraft interface due to vehicle disturbances shall not exceed those defined in Figure 10. The IUS vehicle components shall be designed to operate after exposure to shock environment levels shown in Figure 11.

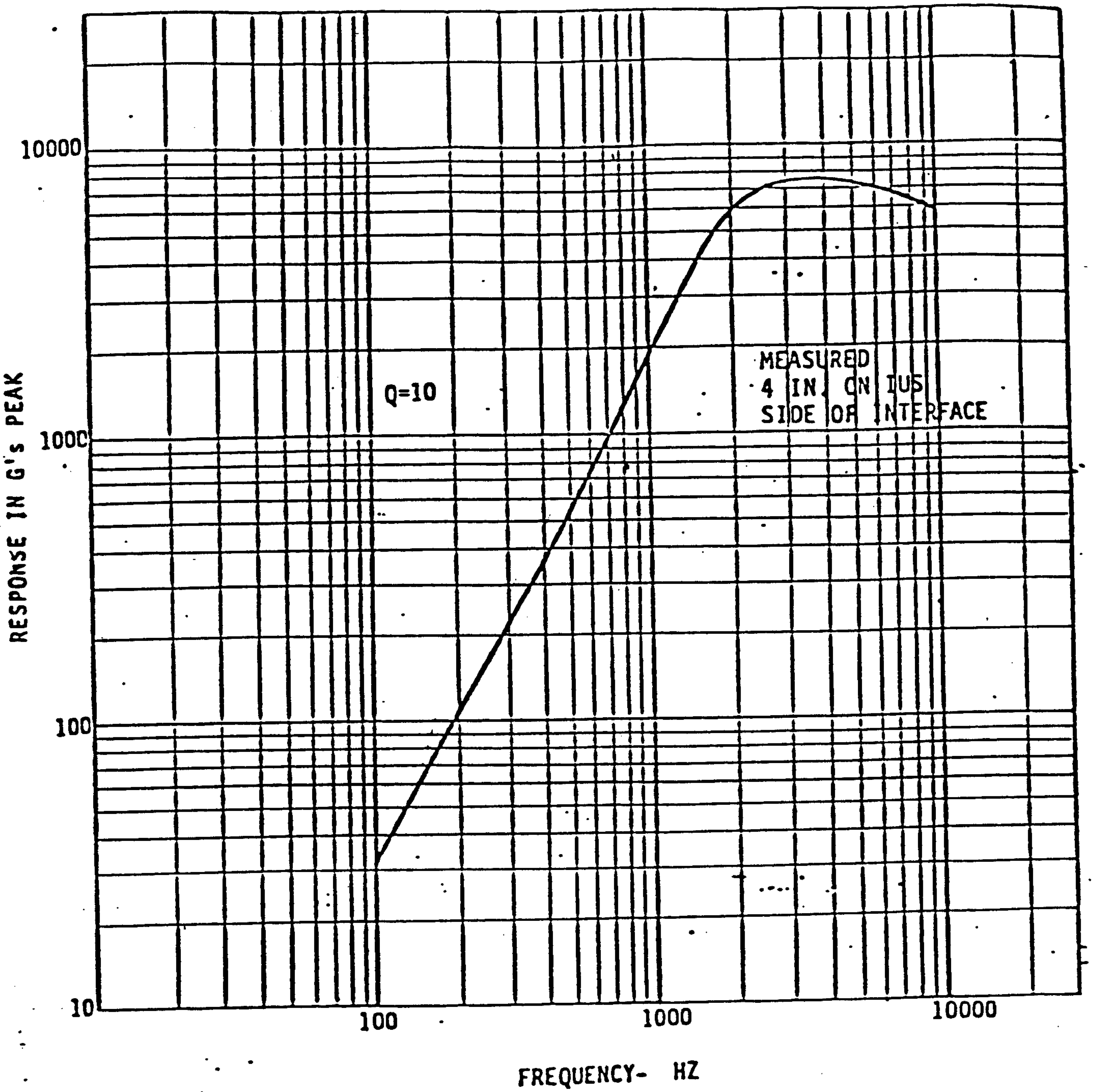


FIGURE 11

SHOCK RESPONSE SPECTRA DUE TO SPACECRAFT DISTURBANCES

FIGURE 2-1 PIDS SHOCK REQUIREMENT

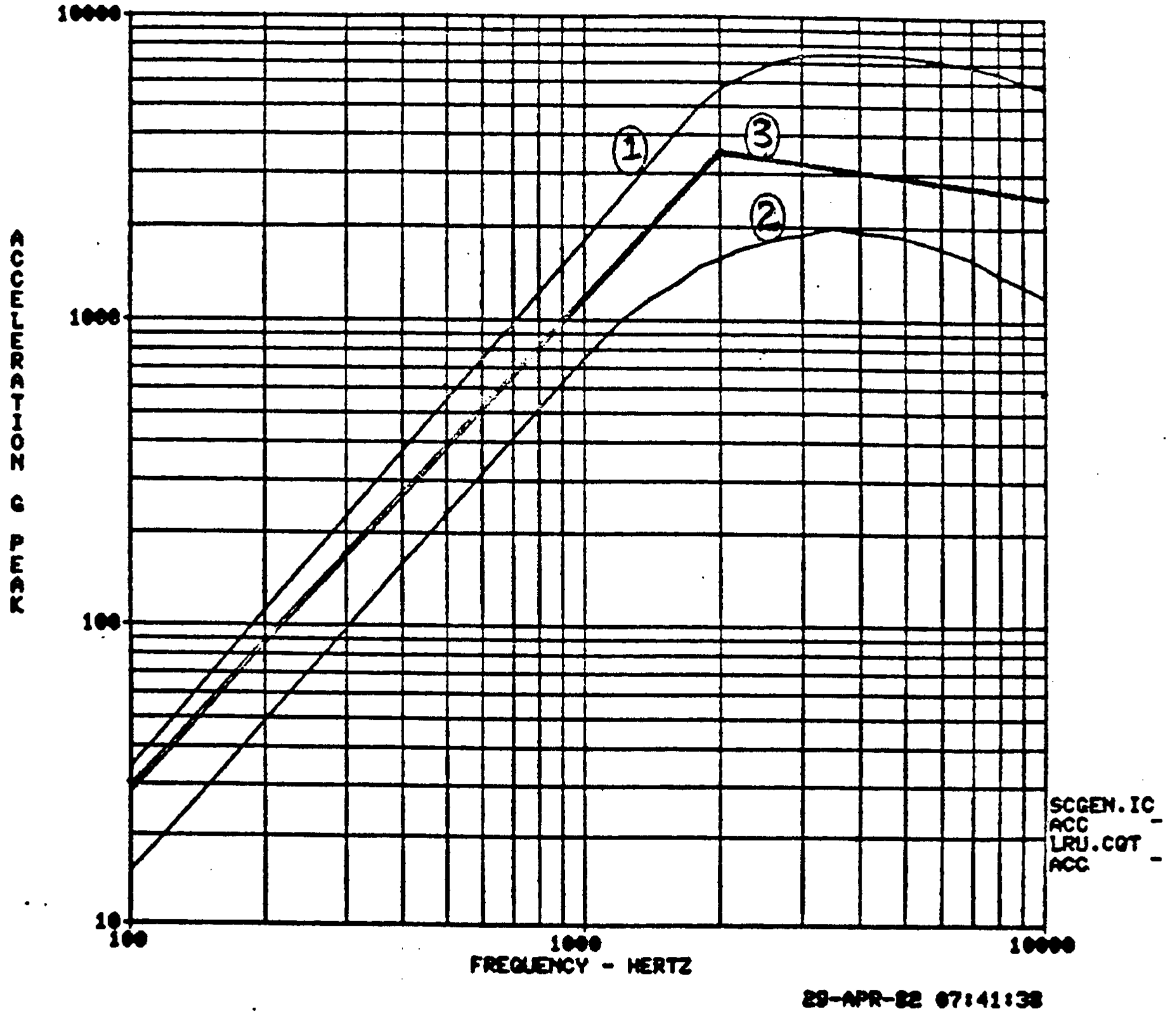


FIGURE 2-2 DESIGN REQUIREMENTS COMPARISON

1 *PIDS, Spacecraft Generated, 4 Inches on IUS Side*
2 *IUS Equipment Design Requirement, Nominal*
3 *IUS Induced Shock Envelope at IUS 379 Ring, QTV*

3.0 SHOCK ANALYSIS

IUS Components

Figure 1 lists the IUS components evaluated for compatibility with the PIDS shock. The figure also indicates the need for the component to function before or after spacecraft separation from IUS.

Prediction Method

The IUS component response to spacecraft induced shock was calculated using the following relationship.

$$S_c = TF \times S_s$$

S_c = Calculated shock spectrum at the IUS component location

S_s = PIDS shock spectrum, figure 2-1

TF = Transfer function between S_s and the IUS component

The transfer functions between S_s and the IUS component locations were calculated using shock data from the IUS QTV stage 1/2 separation shock test. The procedure for calculating the transfer functions is described in section 6.

4.0 COMPATIBILITY EVALUATION

Compatibility Criteria

The compatibility of the IUS components with the spacecraft induced shock was evaluated by comparing the predicted component shock response with the component design requirement and the component qualification test levels. Comparison of the predicted response and the qualification test levels was made only if the prediction was greater than the component design requirement. The IUS component is considered to be compatible with the spacecraft shock if one of the following conditions exist:

(1) the component design requirement is equal to or greater than the predicted response;

(2) the component qualification test level is at least 6 db greater than the predicted response;

(3) the component is located on IUS stage 1.

Results

The results of the compatibility evaluation are summarized in figure 1. The comparisons of the predicted response with the design requirement or qualification test level are shown in figures 4-1 thru 4-32.

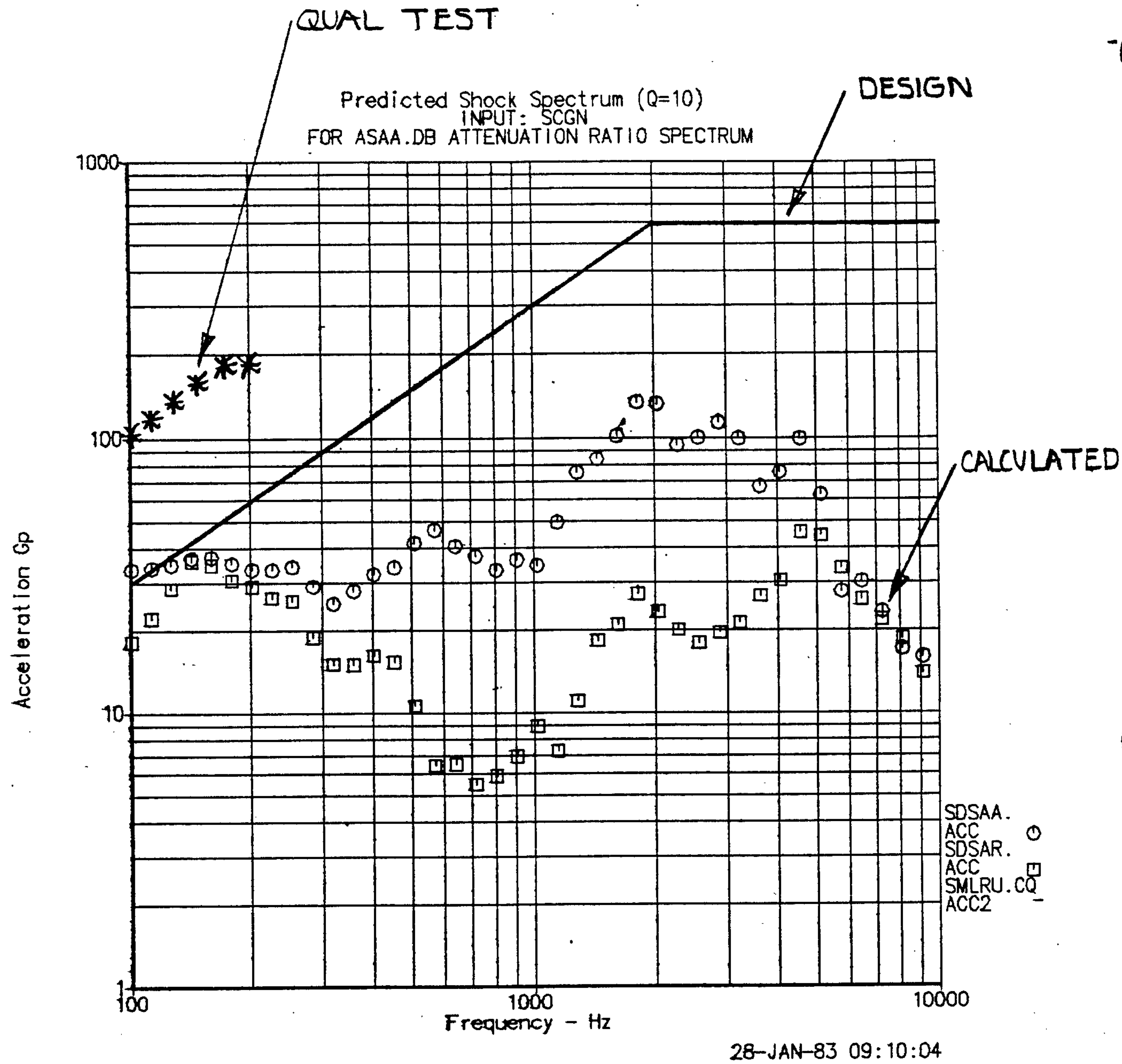
Shock response predictions were not made for all of the components for the following reasons.

(1) Components located on IUS stage 1 will not be subjected to spacecraft separation shock. Spacecraft induced shocks from events other than separation are assumed to be attenuated by the IUS structure to a level which is not significant.

(2) The RCS manifold consists of pressure lines. The lines are not considered to be susceptible to pyrotechnic shock.

(3) The T34D/IUS destruct battery, the T34D/IUS destruct system and the T34D/IUS safe and arm are not required to function after T34D/IUS separation. The spacecraft shocks will normally occur after these items have served their function.

(4) There were no pyrotechnic shock design or test requirements specified for the Extendable Exit Cone (EEC), therefore a compatibility analysis was not conducted.



SAFE & ARM DEVICE (SRM 2) RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS 4 IN. FROM INTERFACE, IUS SIDE

○ Axial

□ Radial

CALC	GB	28JAN83	REVISED	DATE	FIGURE 4-1
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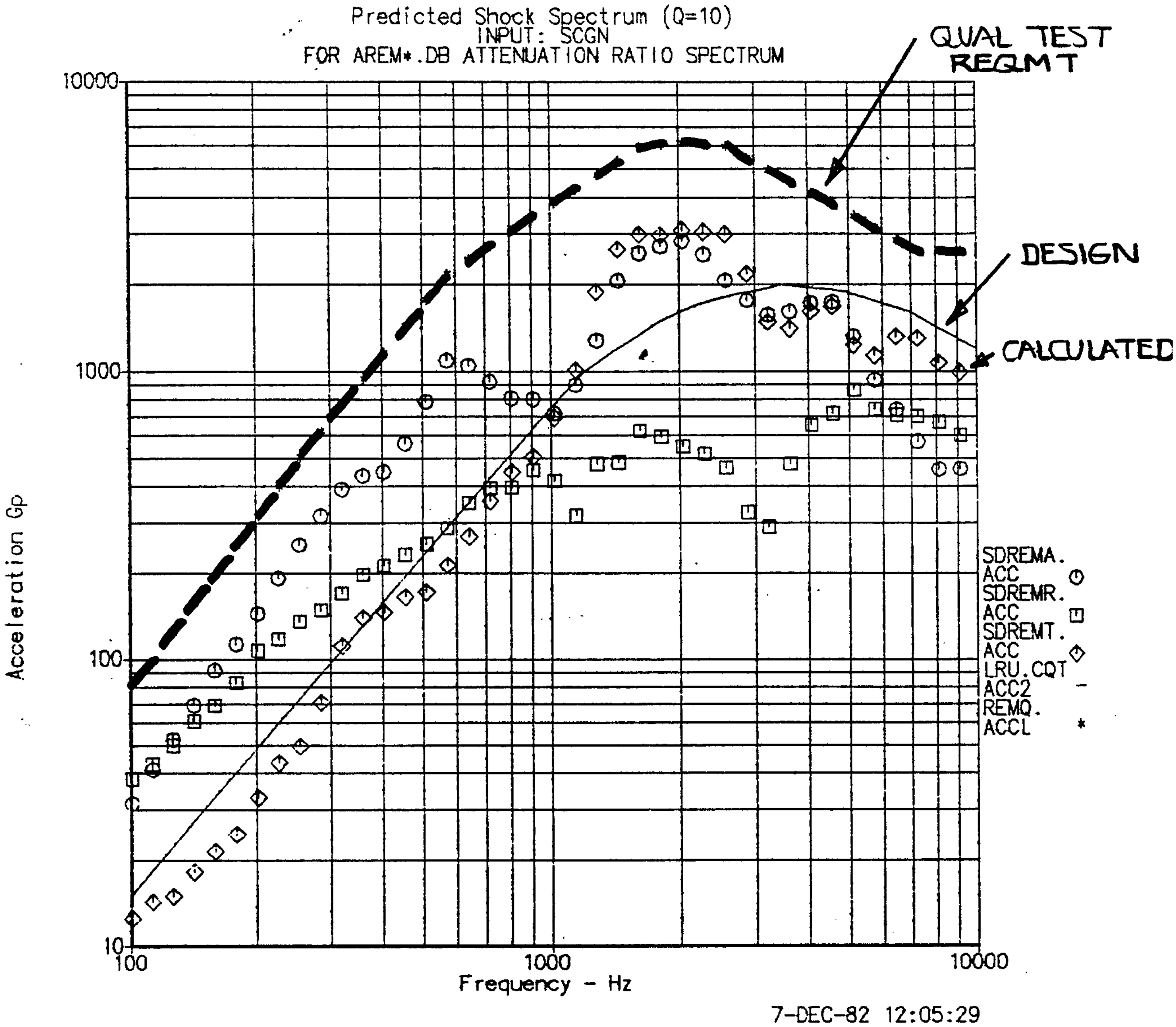

REM RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

O Axial □ Radial ◇ Tangential

CALC	CB	7DEC82	REVISED	DATE	FIGURE 4-2	
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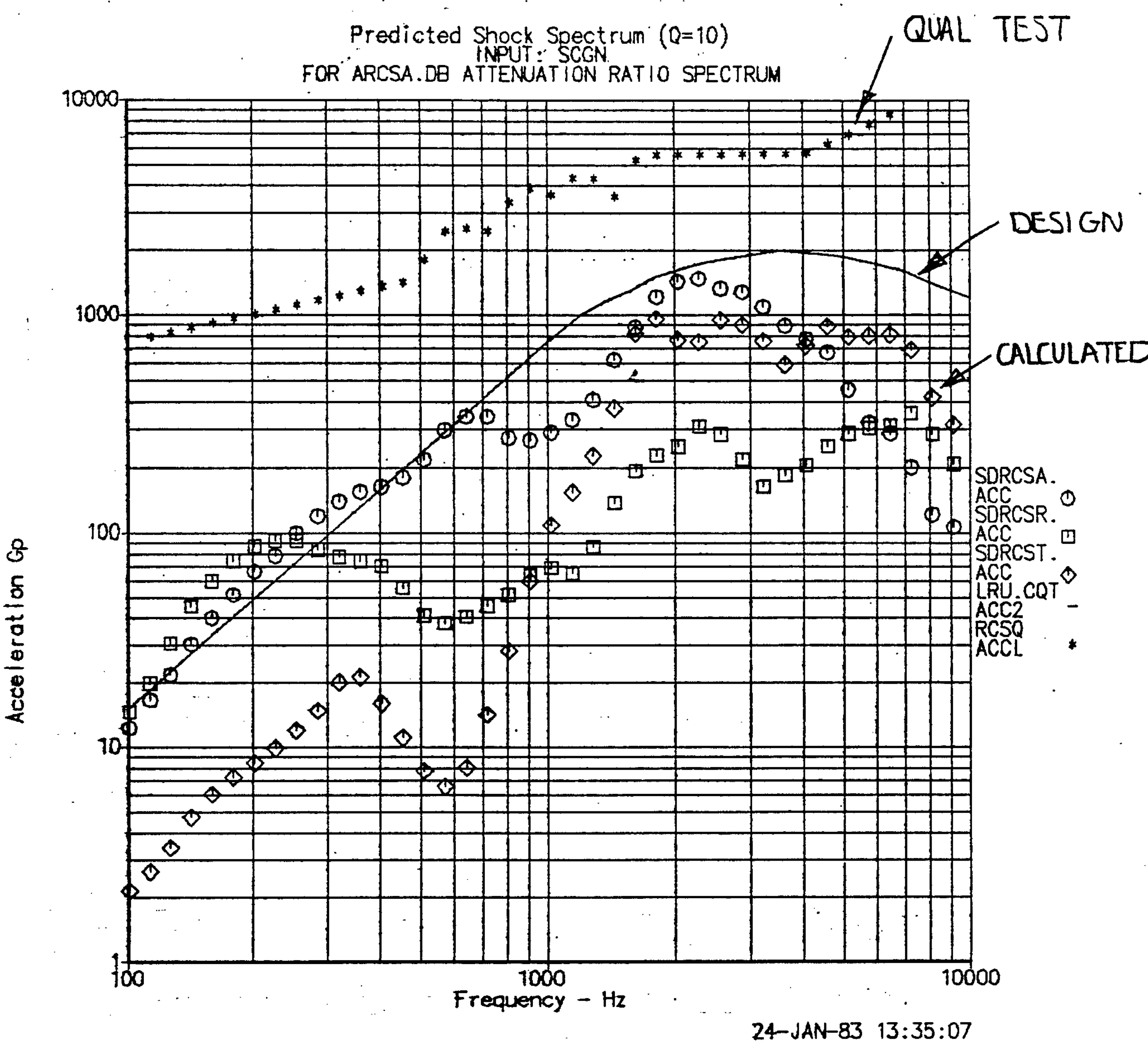

RCS TANK RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS
4 INCHES FROM INTERFACE

O Axial
□ Radial
◇ Tangential

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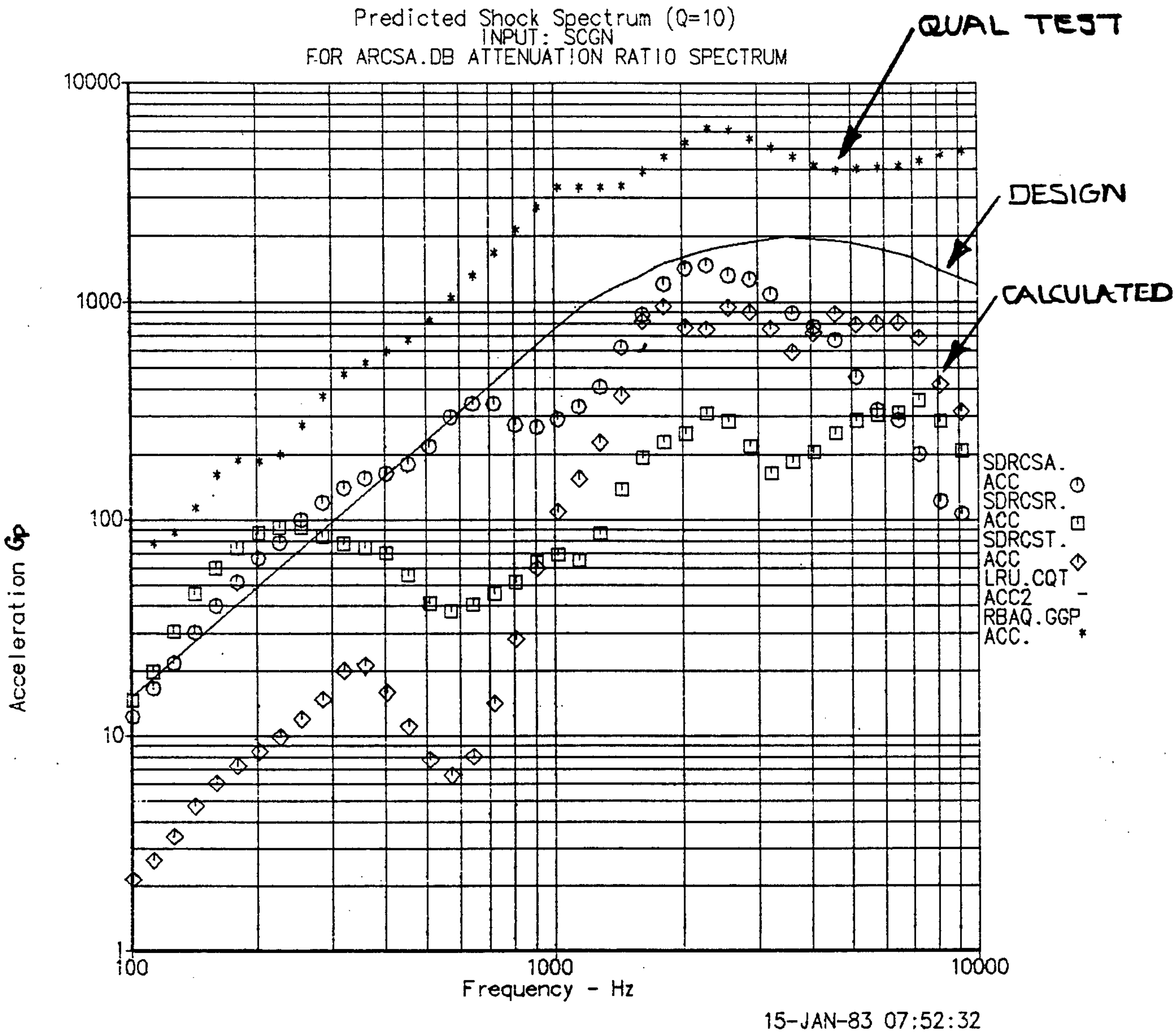

RESISTOR BOARD ASSY RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS 4 IN. FROM I/F, IUS SIDE

O Axial
□ Radial
◇ Tangential

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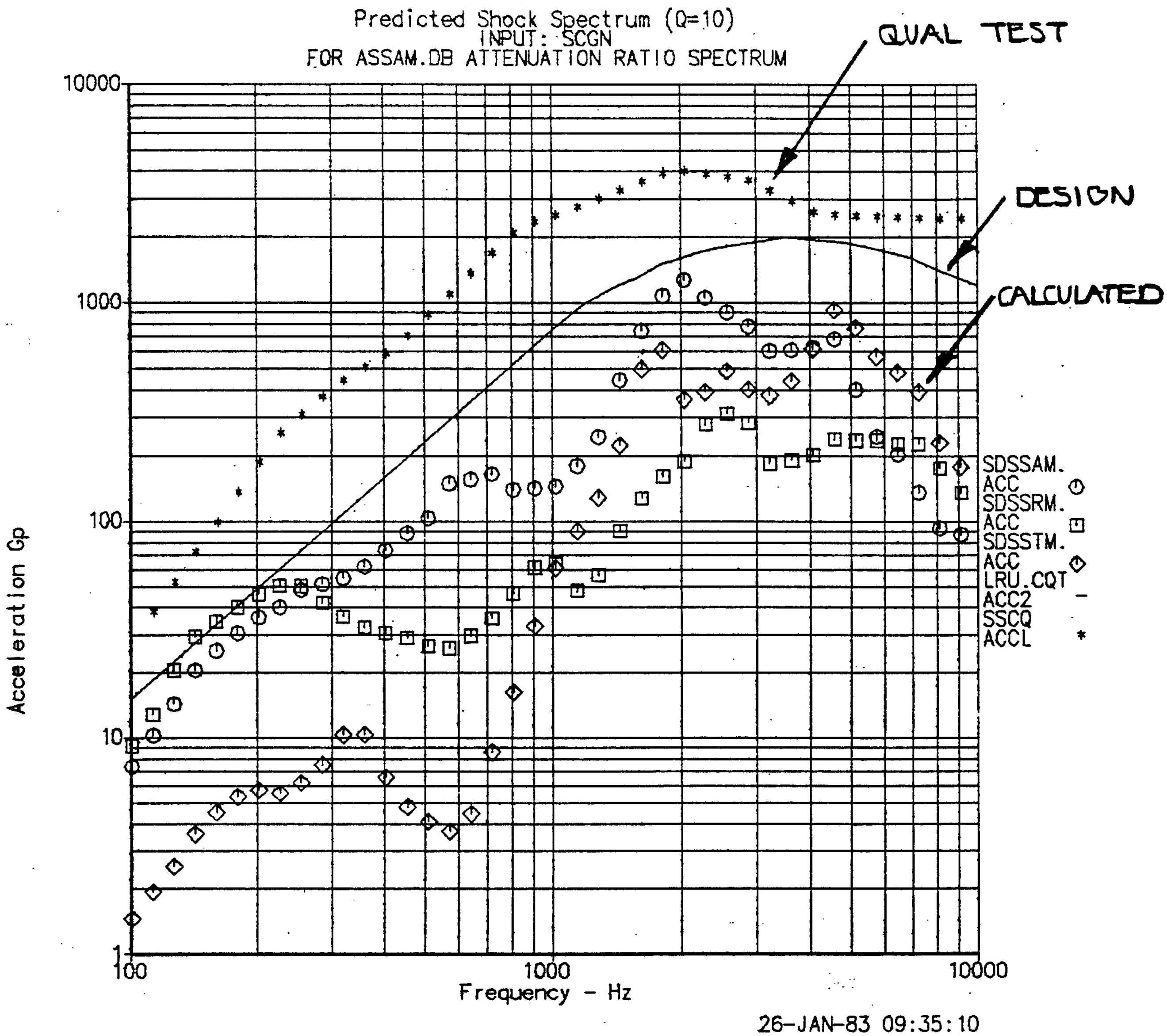

STAR SCANNER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS 4 IN. FROM I/F, IUS SIDE

○ Axial
□ Radial
◇ Tangential

CALC	CB	26JAN83	REVISED	DATE	FIGURE 4-5	
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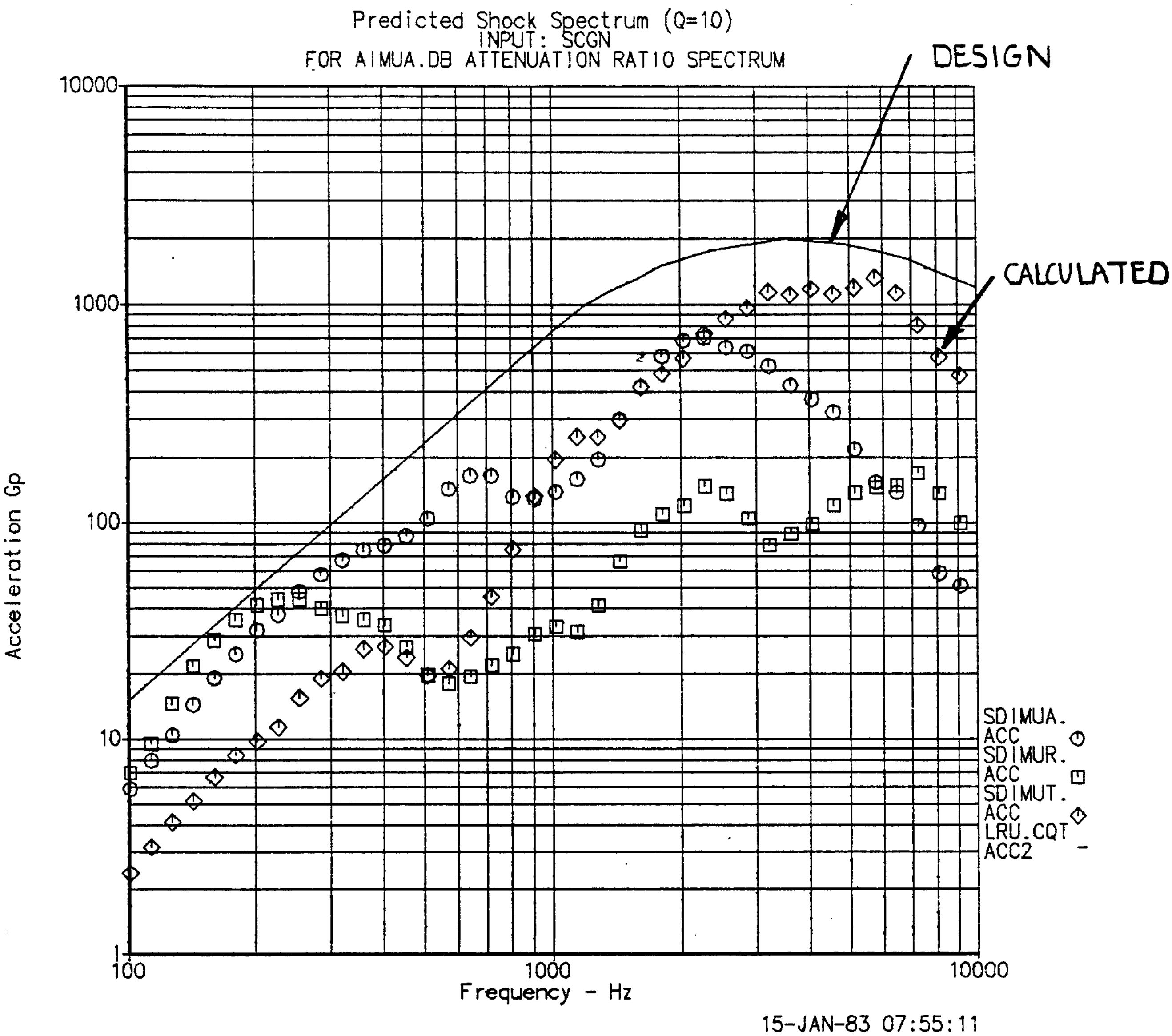

IMU RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS

O Axial
□ Radial
◇ Tangential

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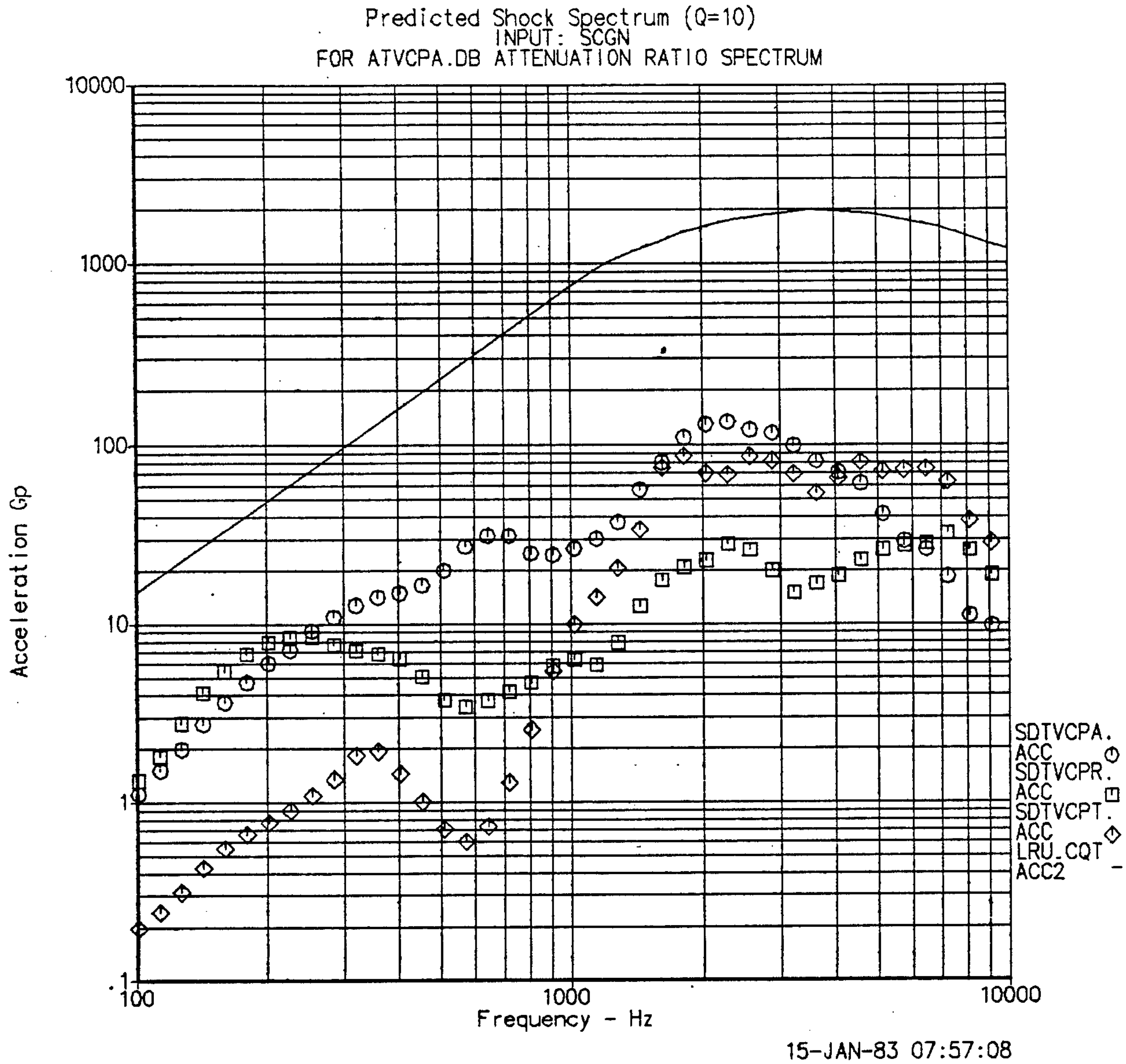

SRM Z TVC ACTUATOR AND POTENTIOMETER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

○ Axial
□ Radial
◇ Tangential

CALC	CJS	15JAN83	REVISED	DATE	FIGURE 4-7	
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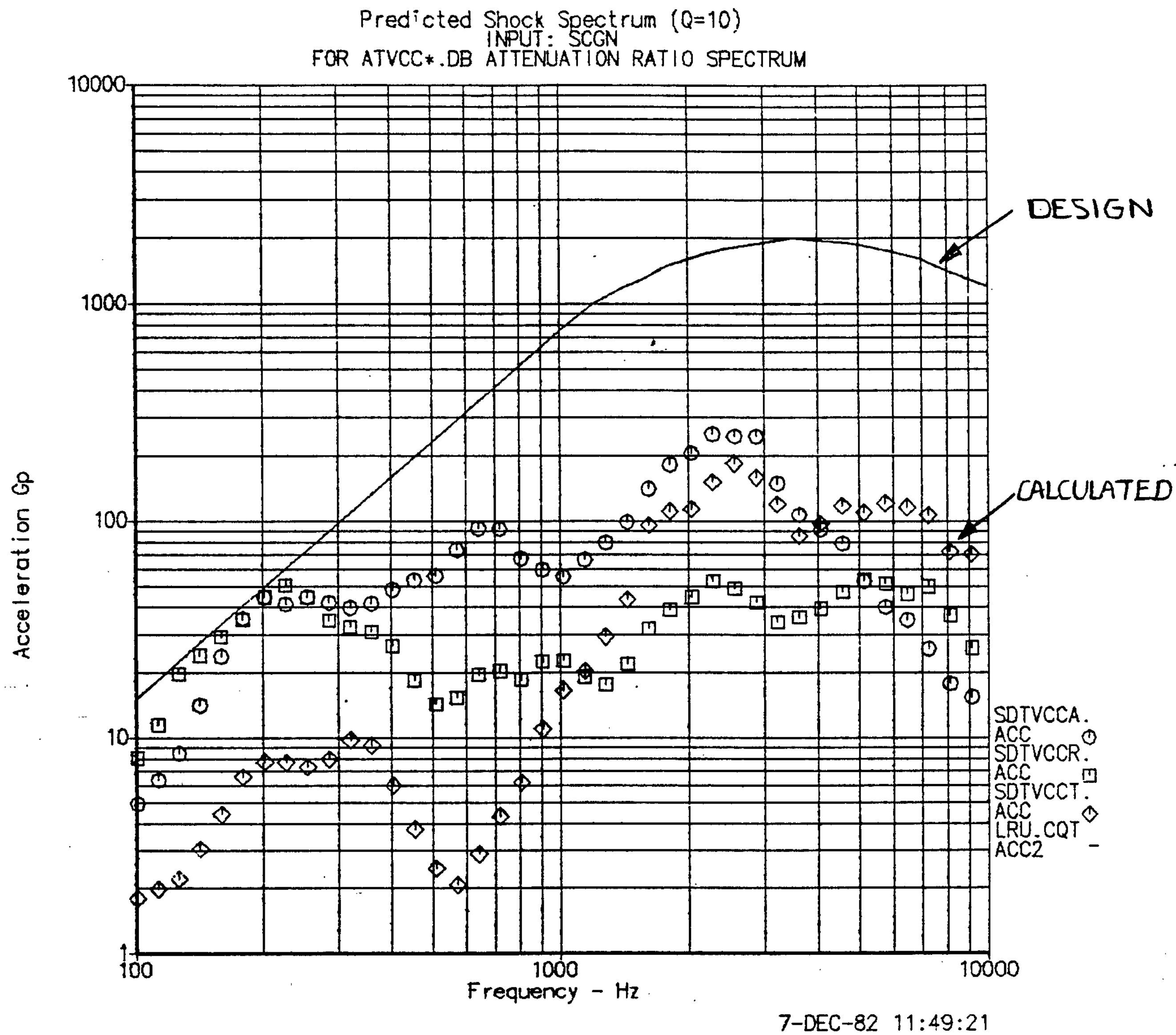

SRM 2 TVC CONTROLLER
RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS

○ Axial   □ Radial   ◇ Tangential

CALC	GB	7DEC82	REVISED	DATE	FIGURE 4-8	
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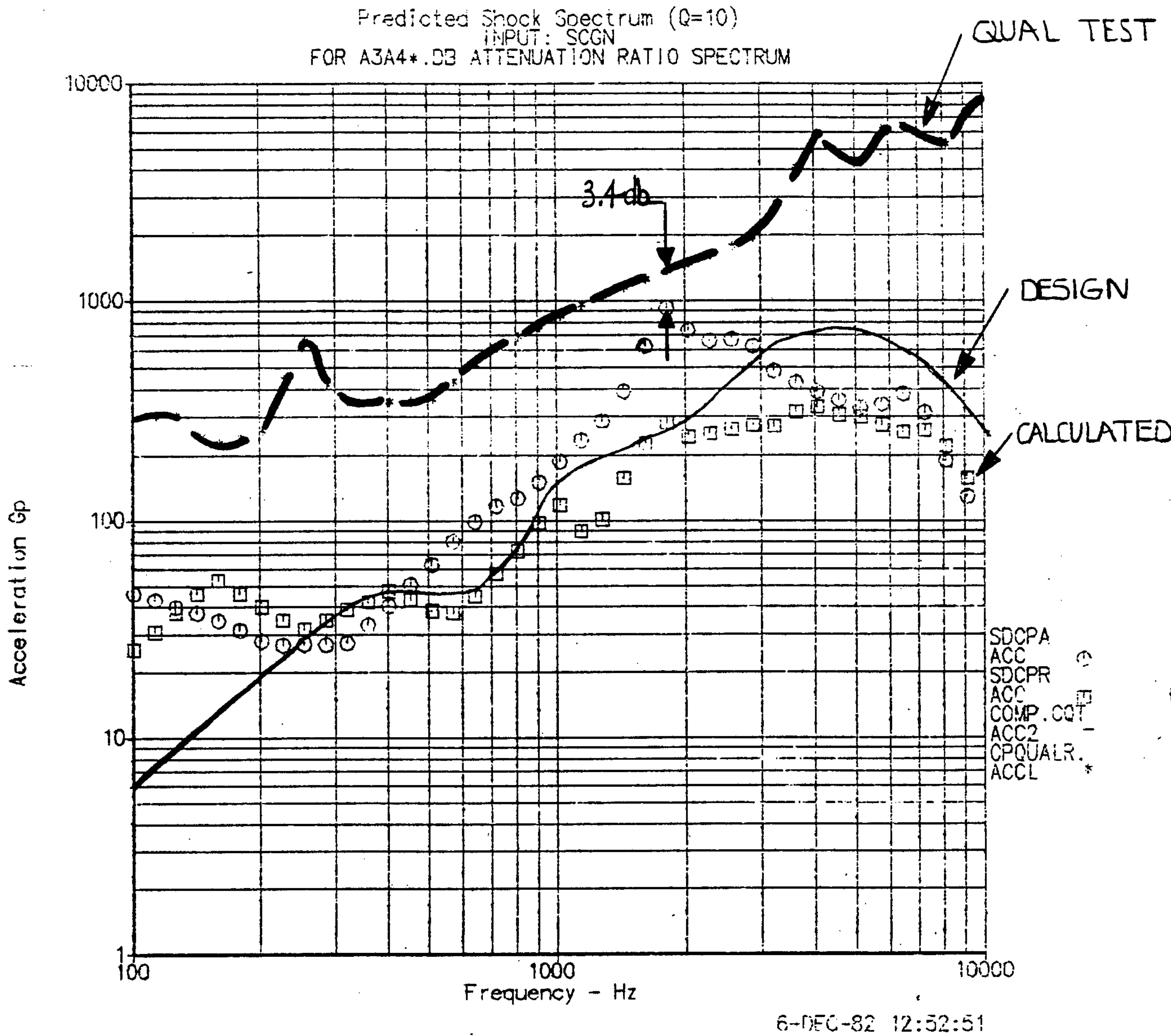

COMPUTER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

○ Axial ☐ Radial

CALC		6DEC82	REVISED	DATE	FIGURE 4-9	
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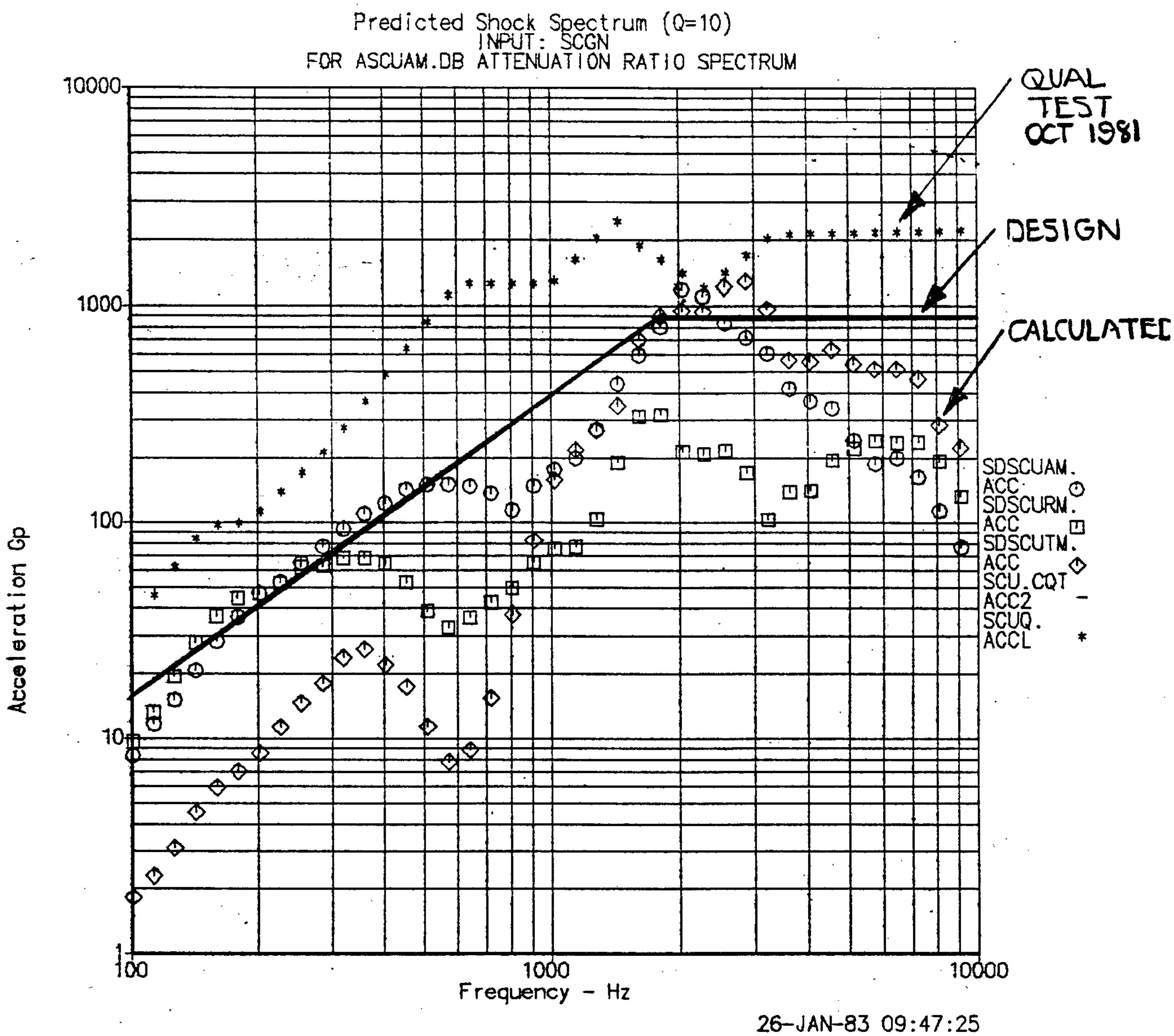

SCU RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS 4 IN. FROM I/F, IUS SIDE

○ Axial

□ Radial

◇ Tangential

CALC	CB	26JAN83	REVISED	DATE	FIGURE 4-10	
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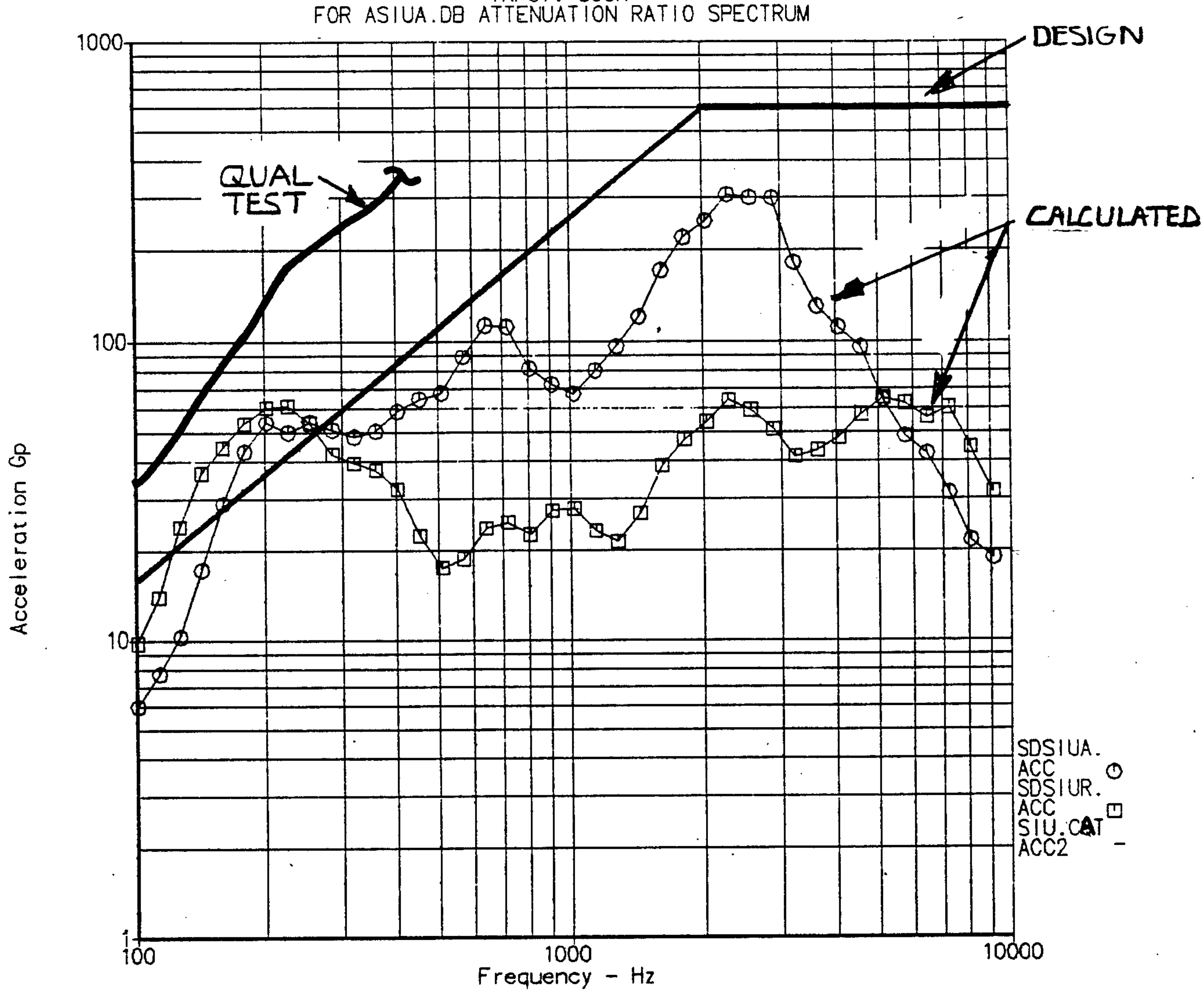
Predicted Shock Spectrum (Q=10)
INPUT: SCGN
FOR ASIUA.DB ATTENUATION RATIO SPECTRUM



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SIU RESPONSE TO
S/C INDUCED SHOCK, PIDS
○ AXIAL
□ RADIAL

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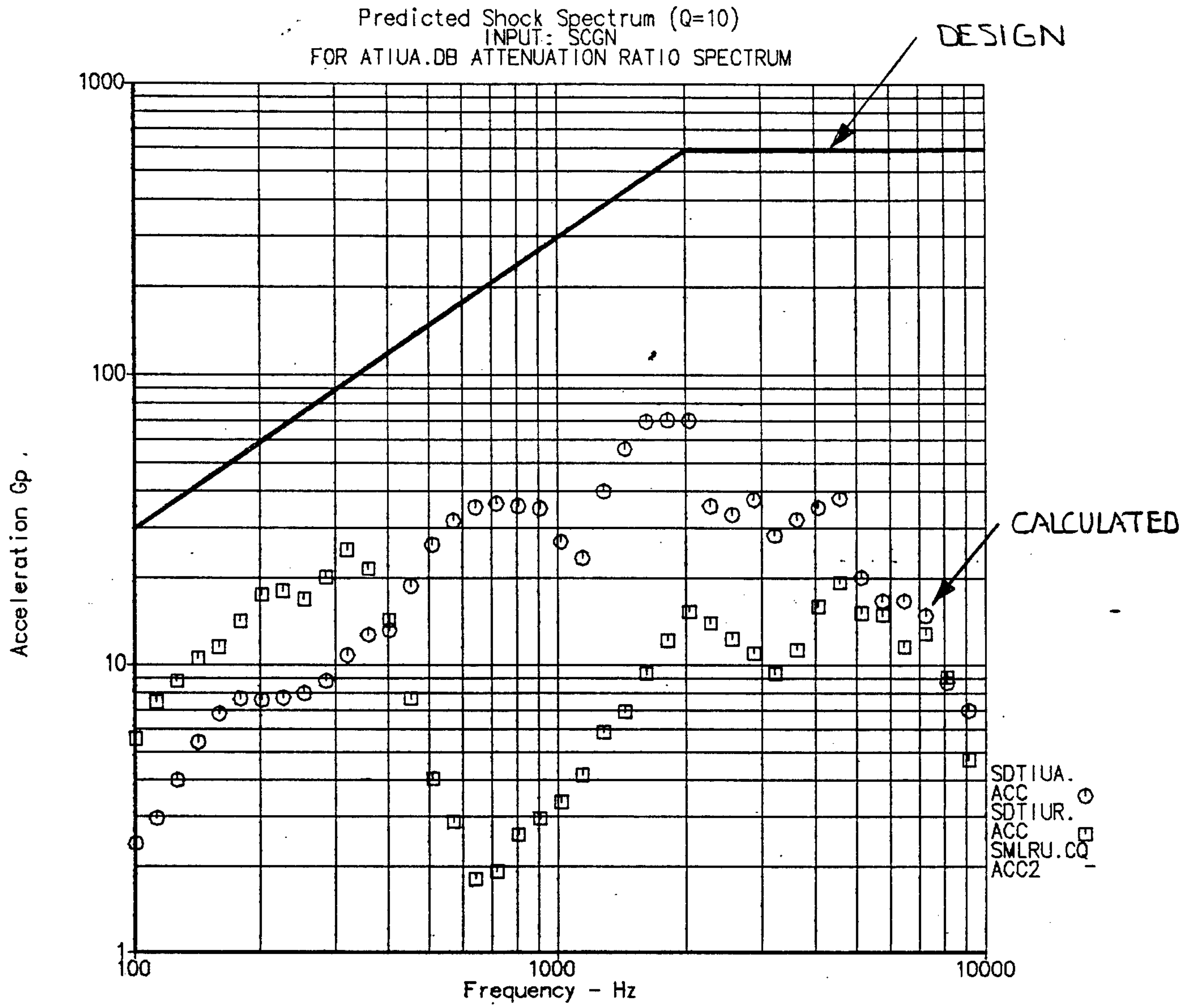

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TIU RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

○ Axial
□ Radial

CALC	GB	15JAN83	REVISED	DATE	FIGURE 4-12	
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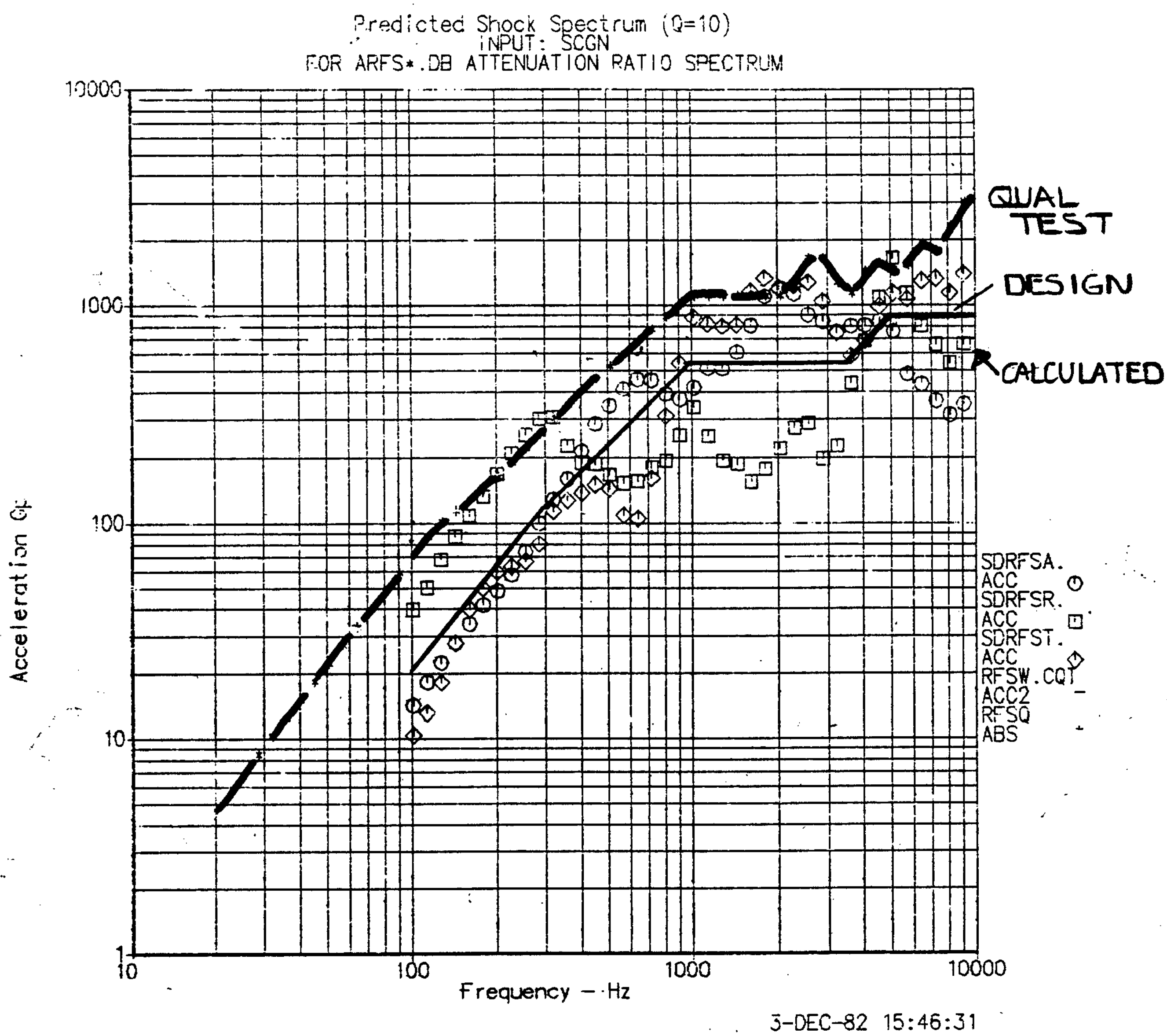

RF SWITCH & RF FAIL SAFE RELAY RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

○ Axial □ Radial ◇ Tangential

CALC	CB	3DEC82	REVISED	DATE	FIGURE 4-13	
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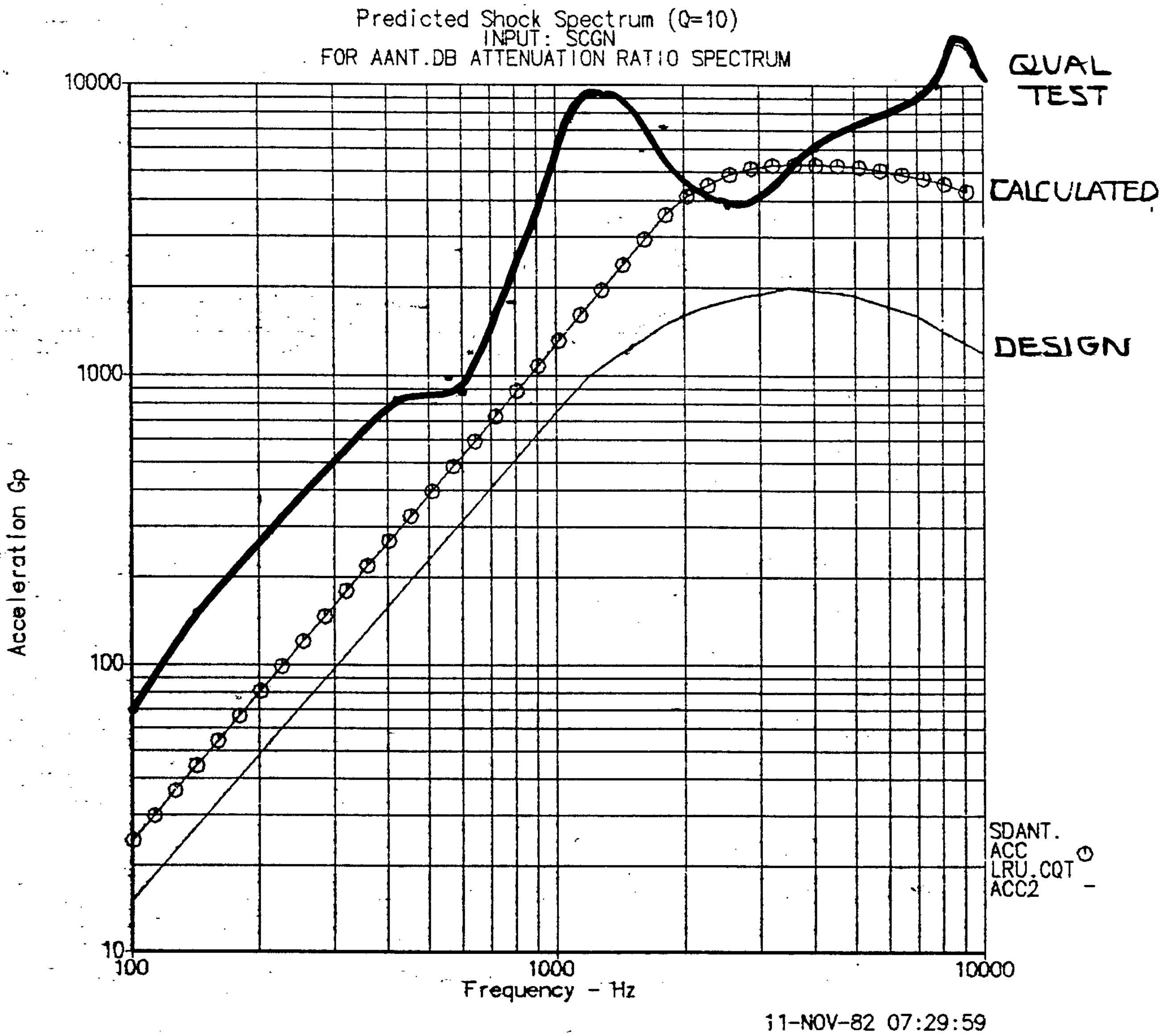

IUS OMNI ANTENNA RESPONSE TO S/C INDUCED SHOCK, PIDS

CALC	CB	11NOV82	REVISED	DATE	FIGURE 4-14	
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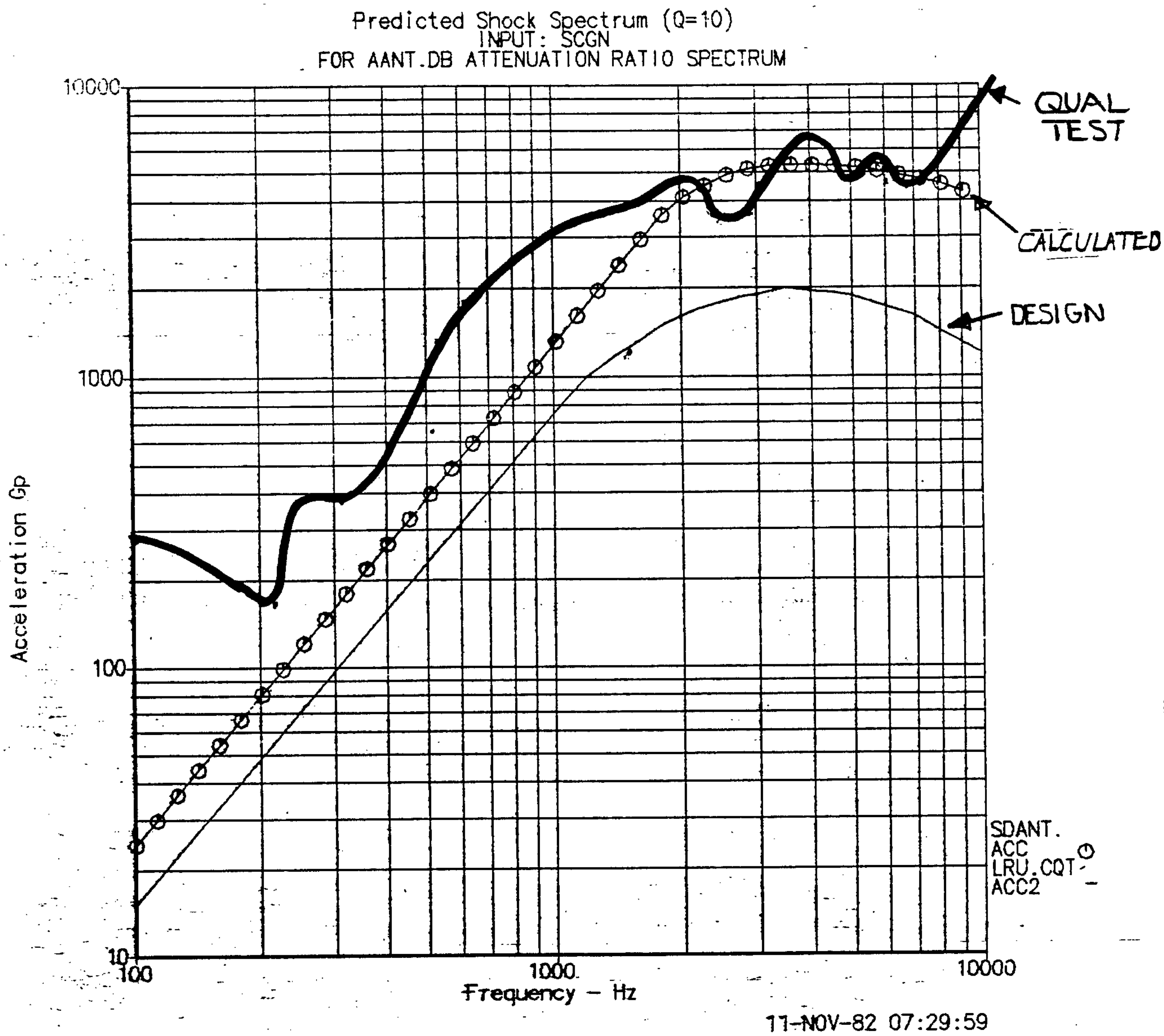

IUS MEDIUM GAIN ANTENNA RESPONSE TO S/C INDUCED SHOCK, PIDS STS CONFIGURATION

All Axes

CALC	CB	11NOV82	REVISED	DATE	FIGURE 4-15	
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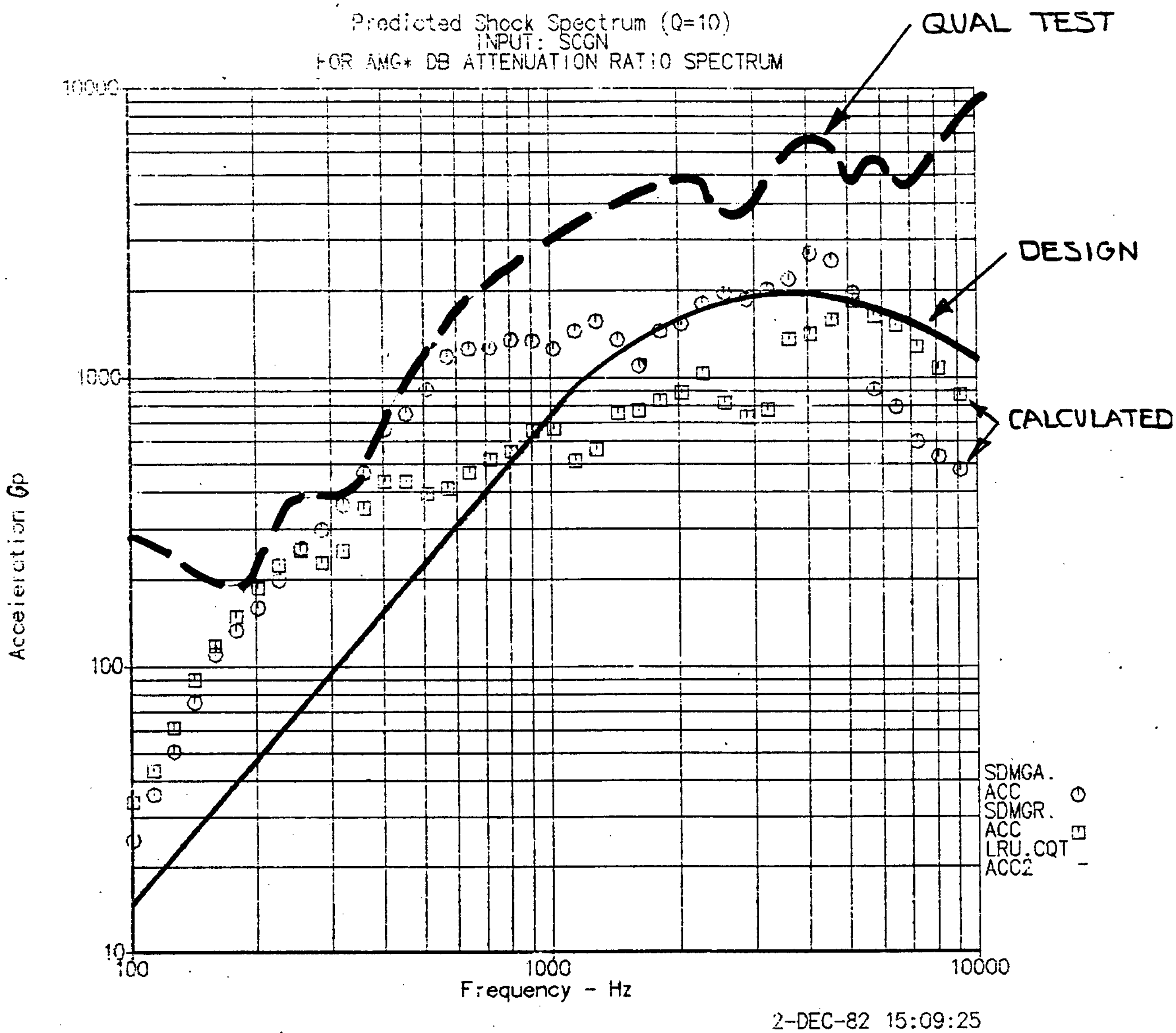

MEDIUM GAIN ANTENNA
RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS
T34D CONFIGURATION

O Axial □ Radial

CALC		2DEC82	REVISED	DATE	FIGURE 4-16	
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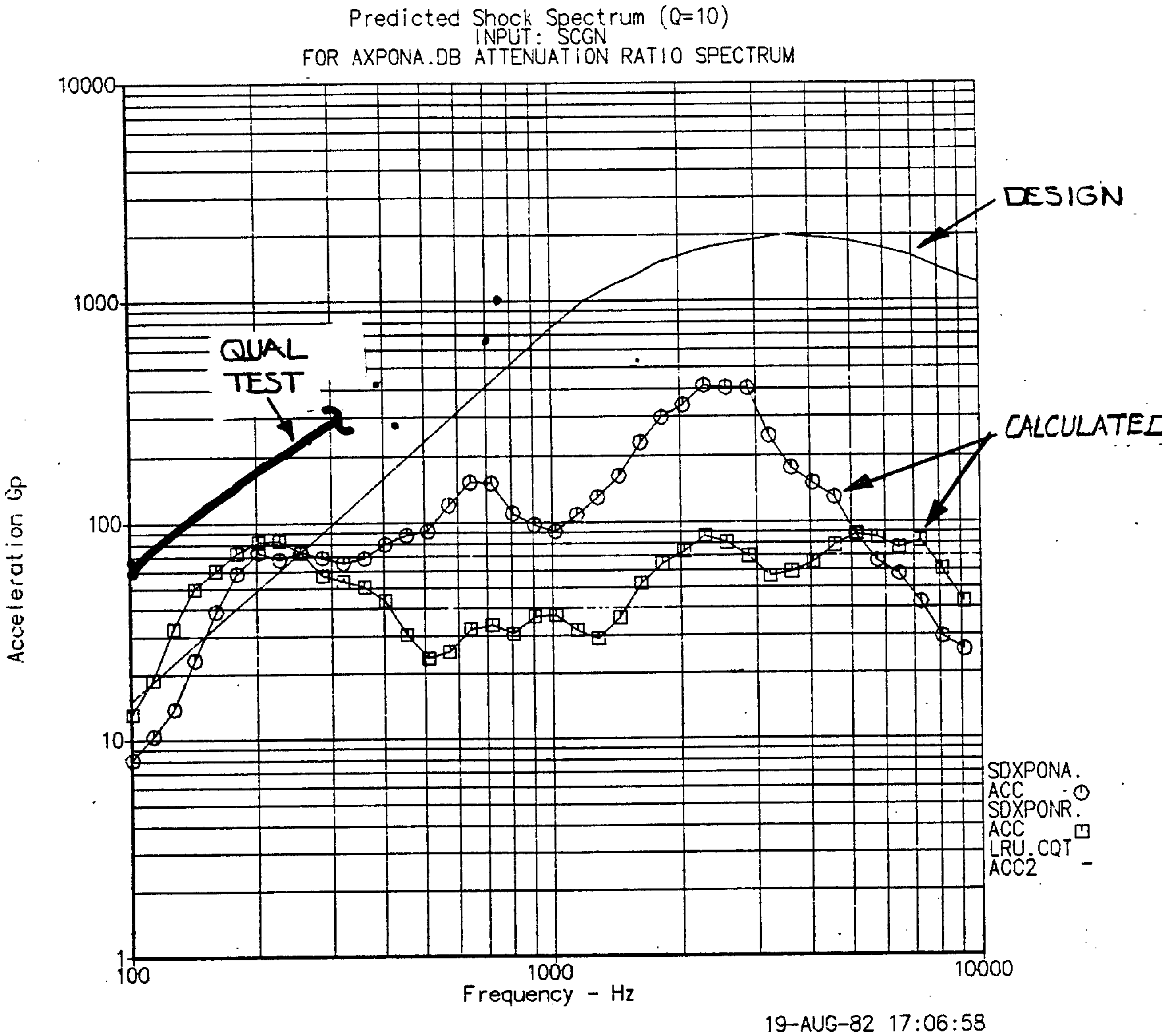

TRANSPONDER RESPONSE TO S/C INDUCED SHOCK, PIDS

O AXIAL

□ RADIAL

CALC	CB	19AUG82	REVISED	DATE	FIGURE 4-17	
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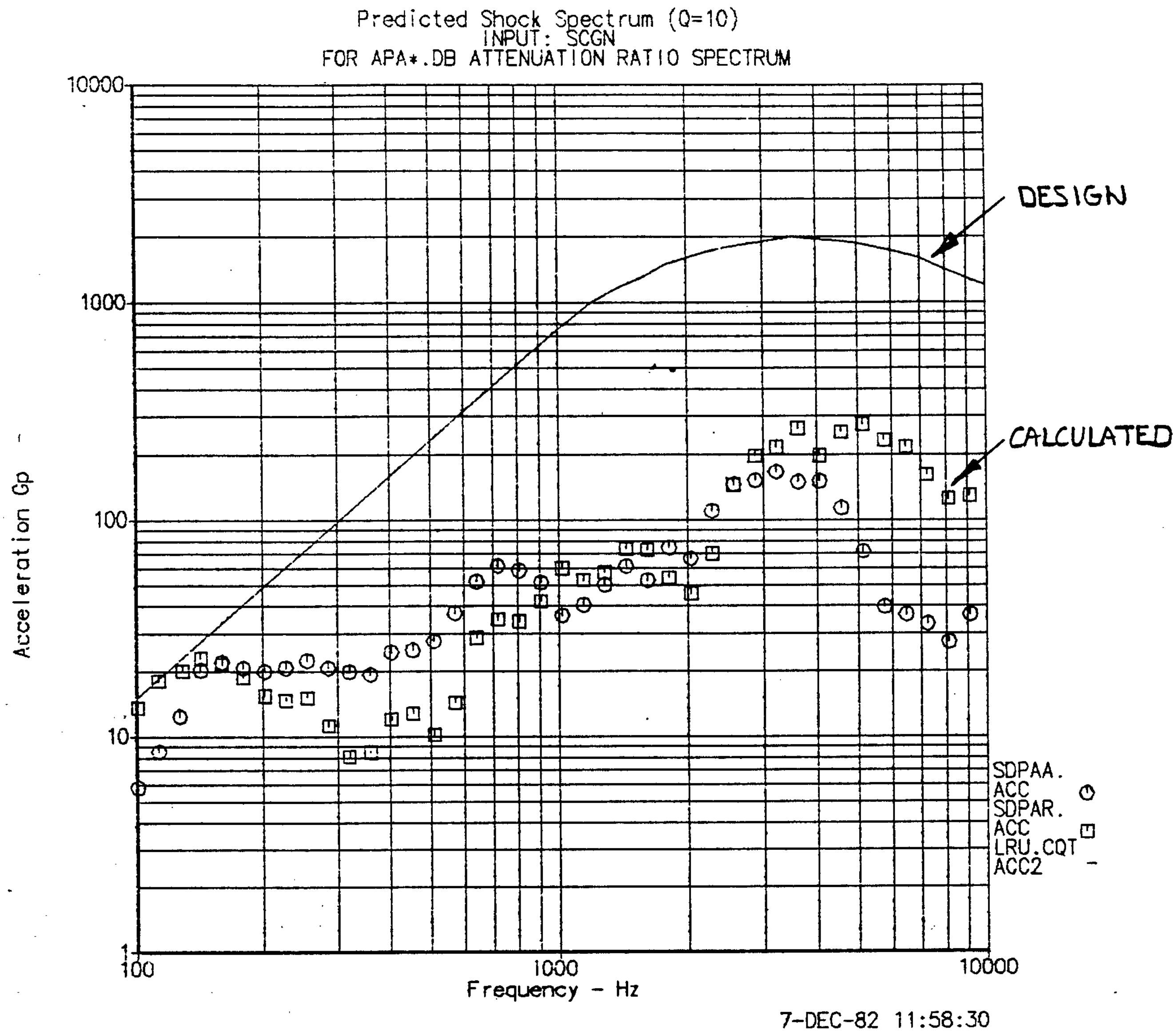

POWER AMPLIFIER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

O Axial □ Radial

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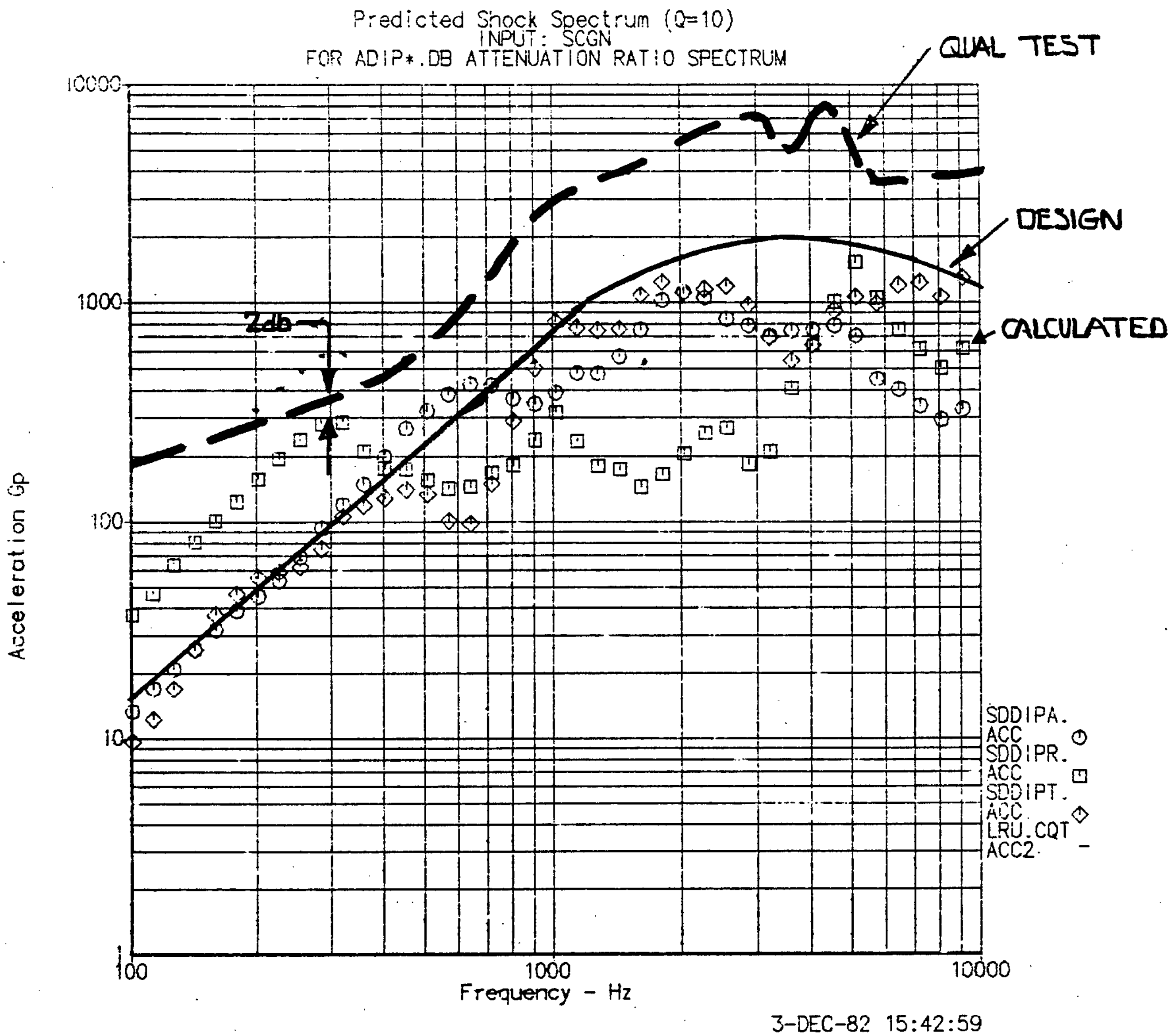

DIPLEXER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

○Axial □Radial ◇Tangential

CALC	CB	3DEC82	REVISED	DATE	FIGURE 4-19	
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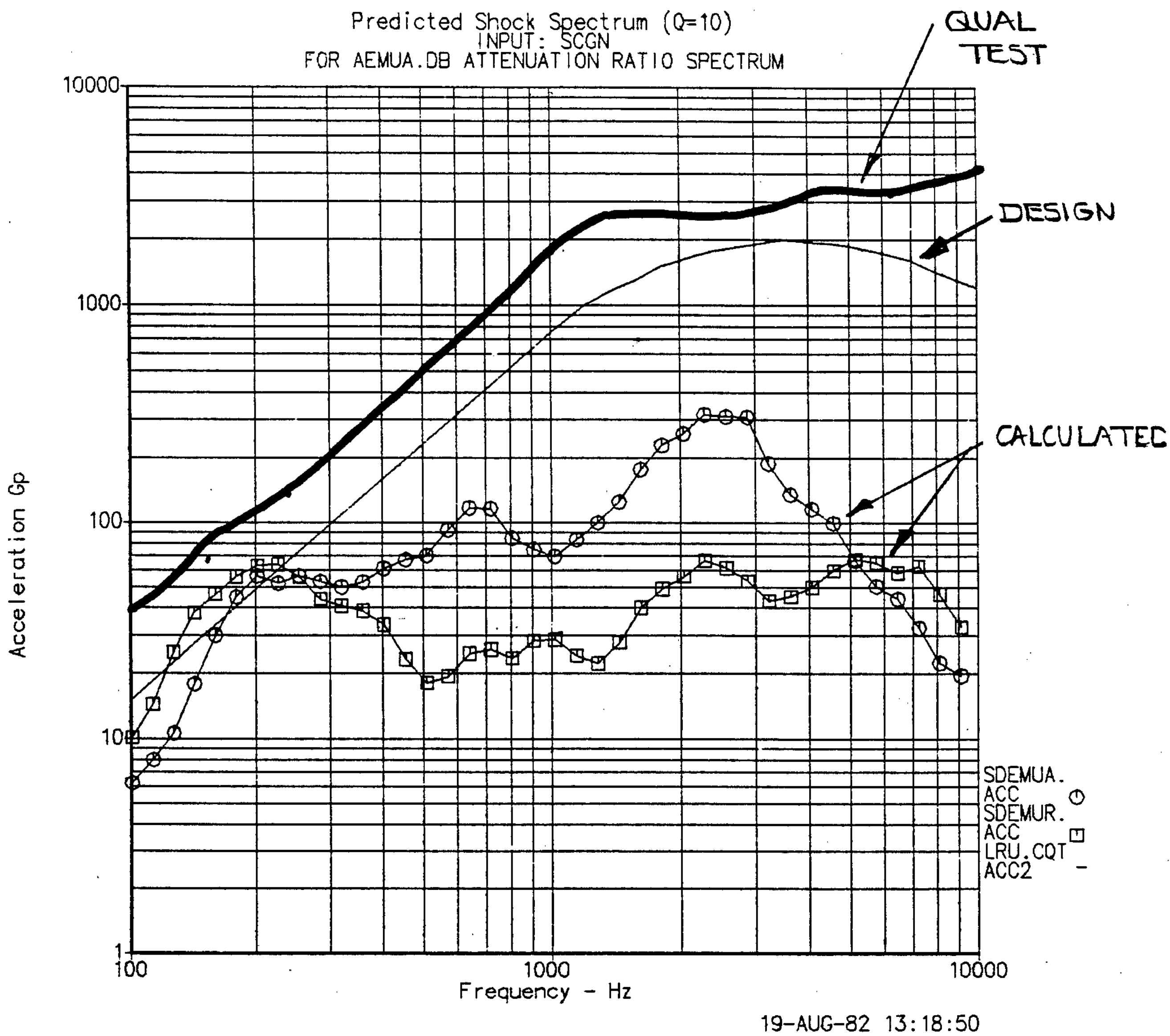

EMU RESPONSE TO
S/C INDUCED SHOCK, PIDS
O AXIAL
□ RADIAL

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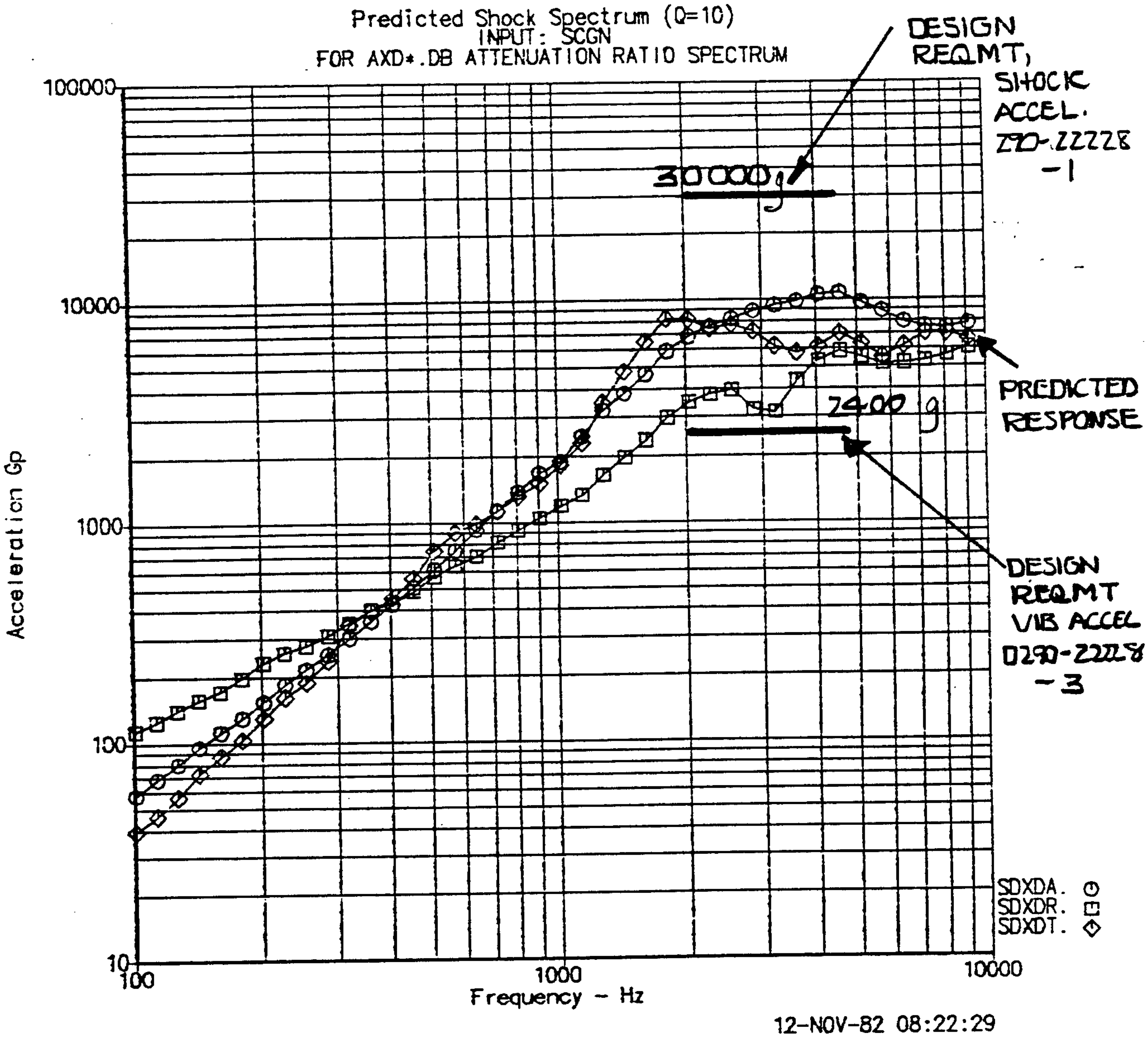

EMU SHOCK/VIBRATION TRANSDUCER
RESPONSE TO
S/C INDUCED SHOCK, PIDS

○ Axial □ Radial ◇ Tangential

CALC	CB	12NOV82	REVISED	DATE	FIGURE 4-21	
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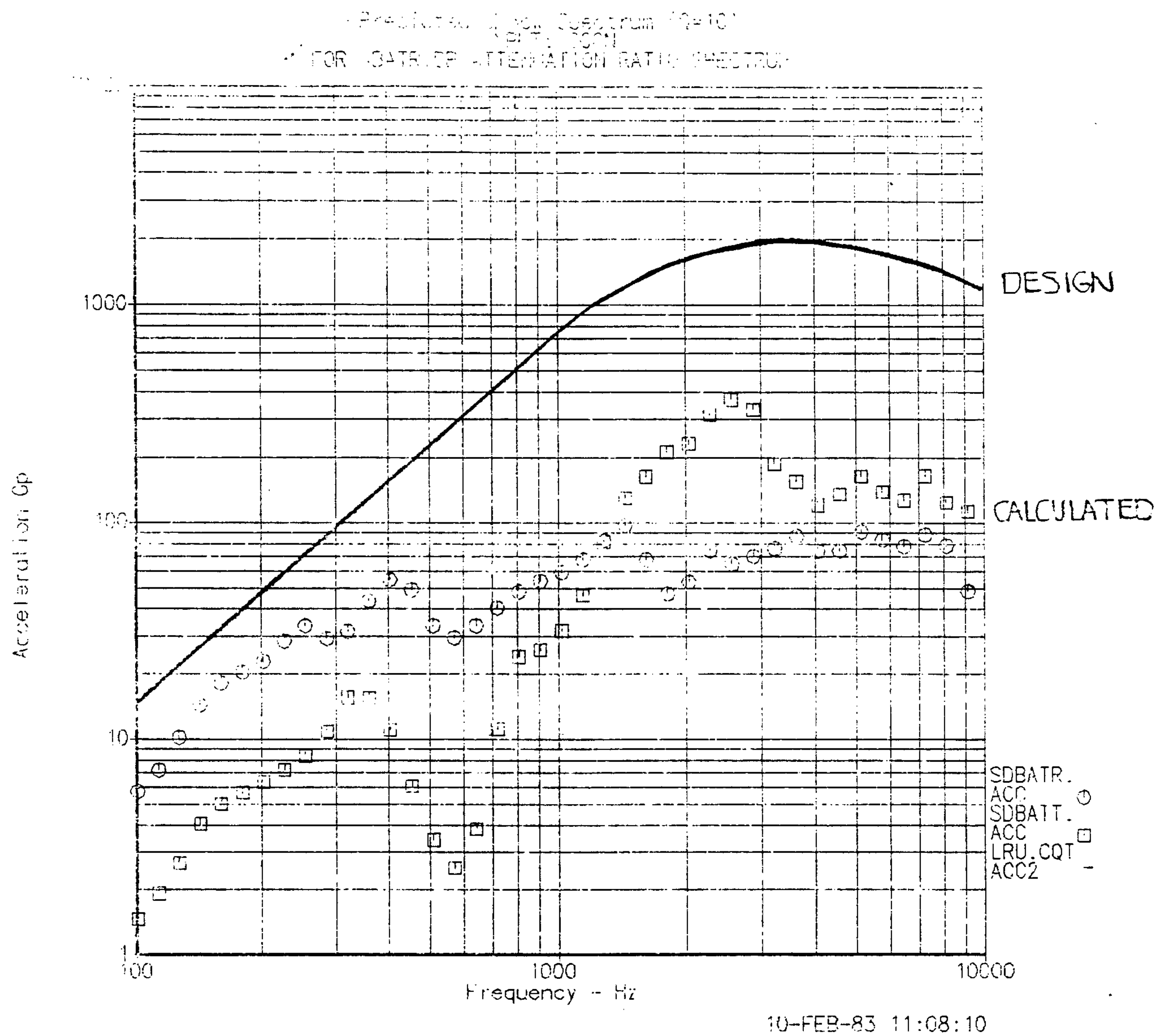

UTILITY BATTERY RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

o Radial □ Tangential

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FIGURE 4-22			
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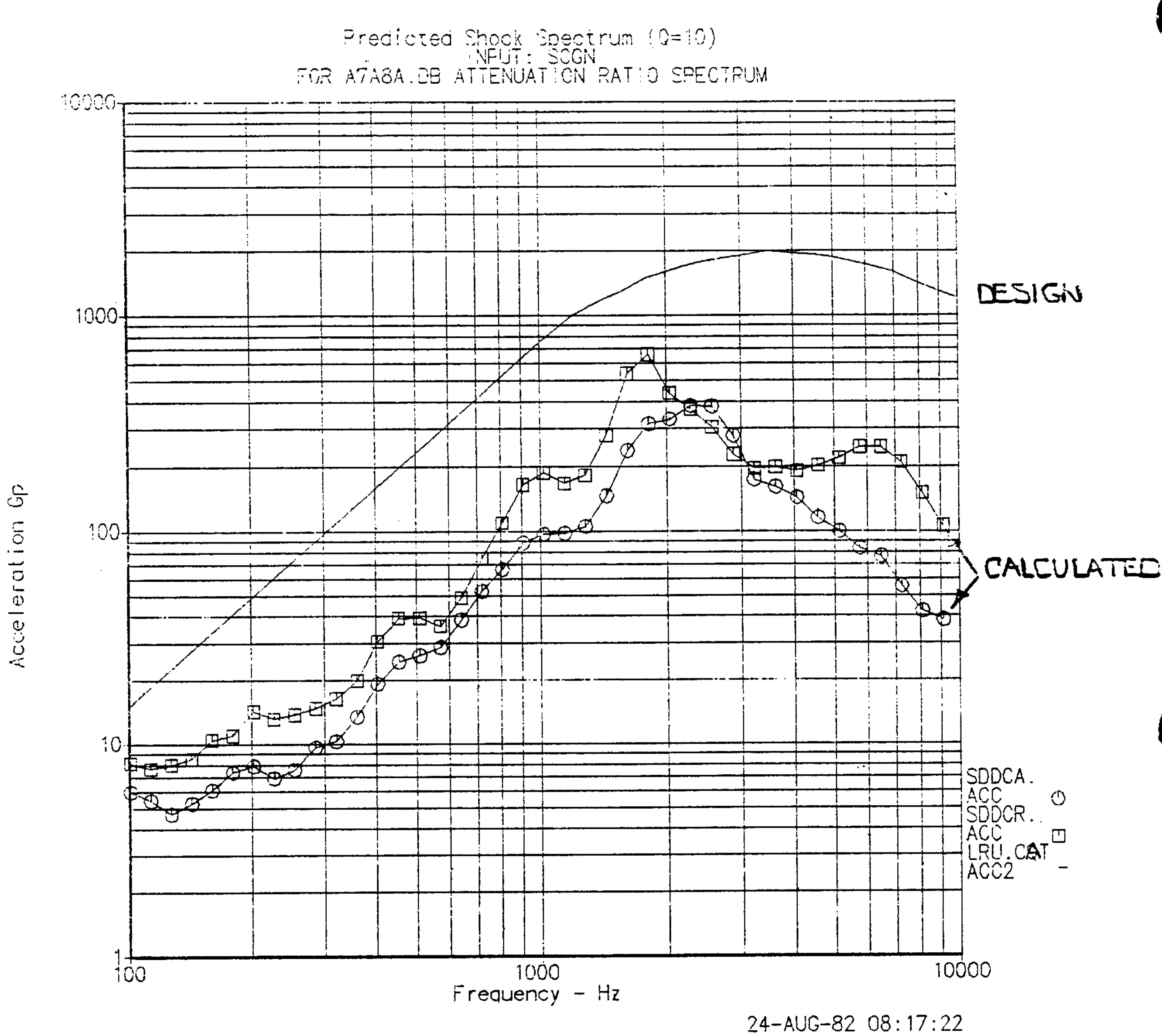

DC-DC CONVERTER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

O Axial □ Radial

CALC	[illegible]	24AUG82	REVISED	DATE	FIGURE 4-23	
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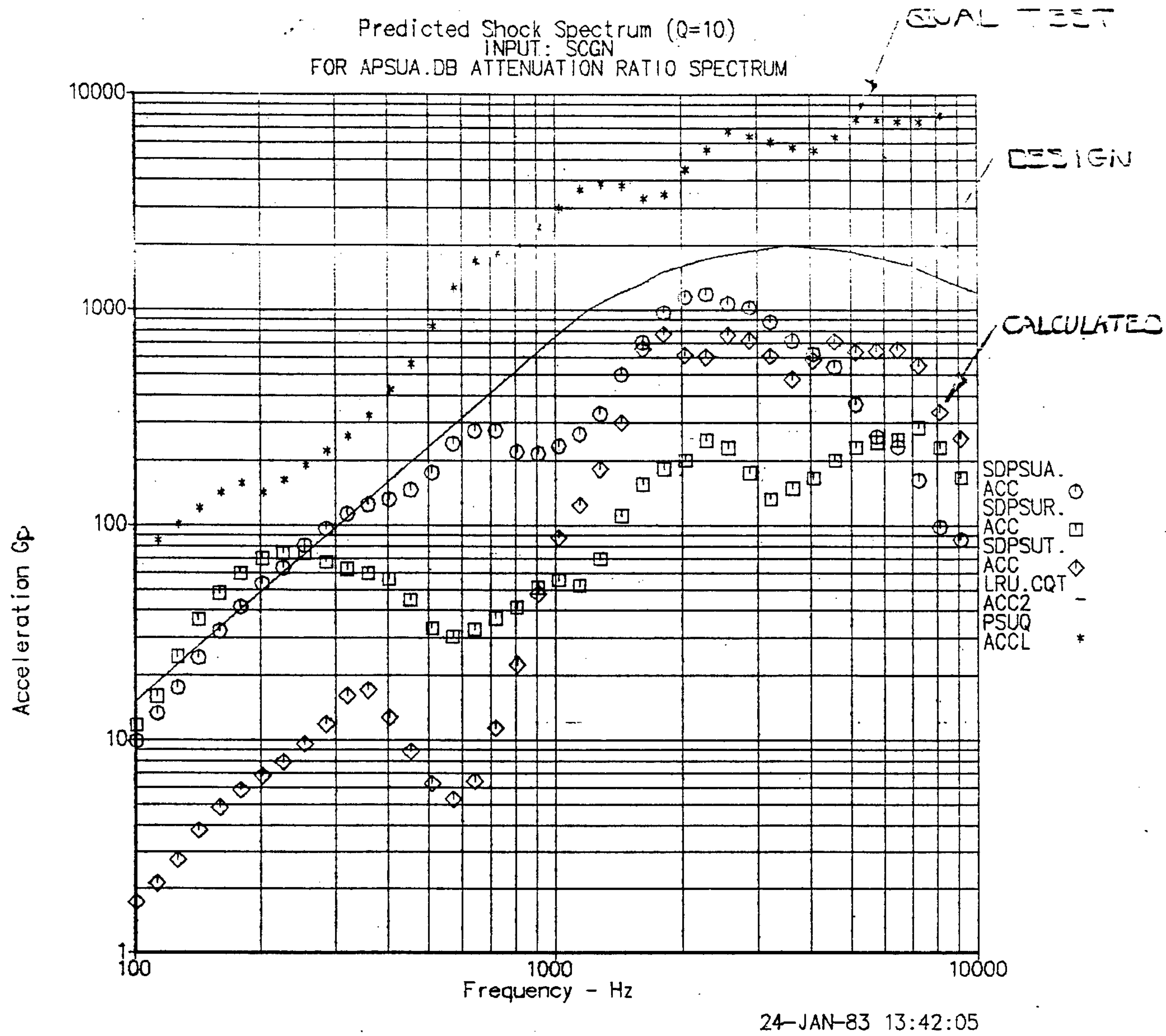

PSU RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS 4 IN. FROM I/F, IUS SIDE

○ Axial
□ Radial
◇ Tangential

CALC	GB	24JAN83	REVISED	DATE	FIGURE 4-24	
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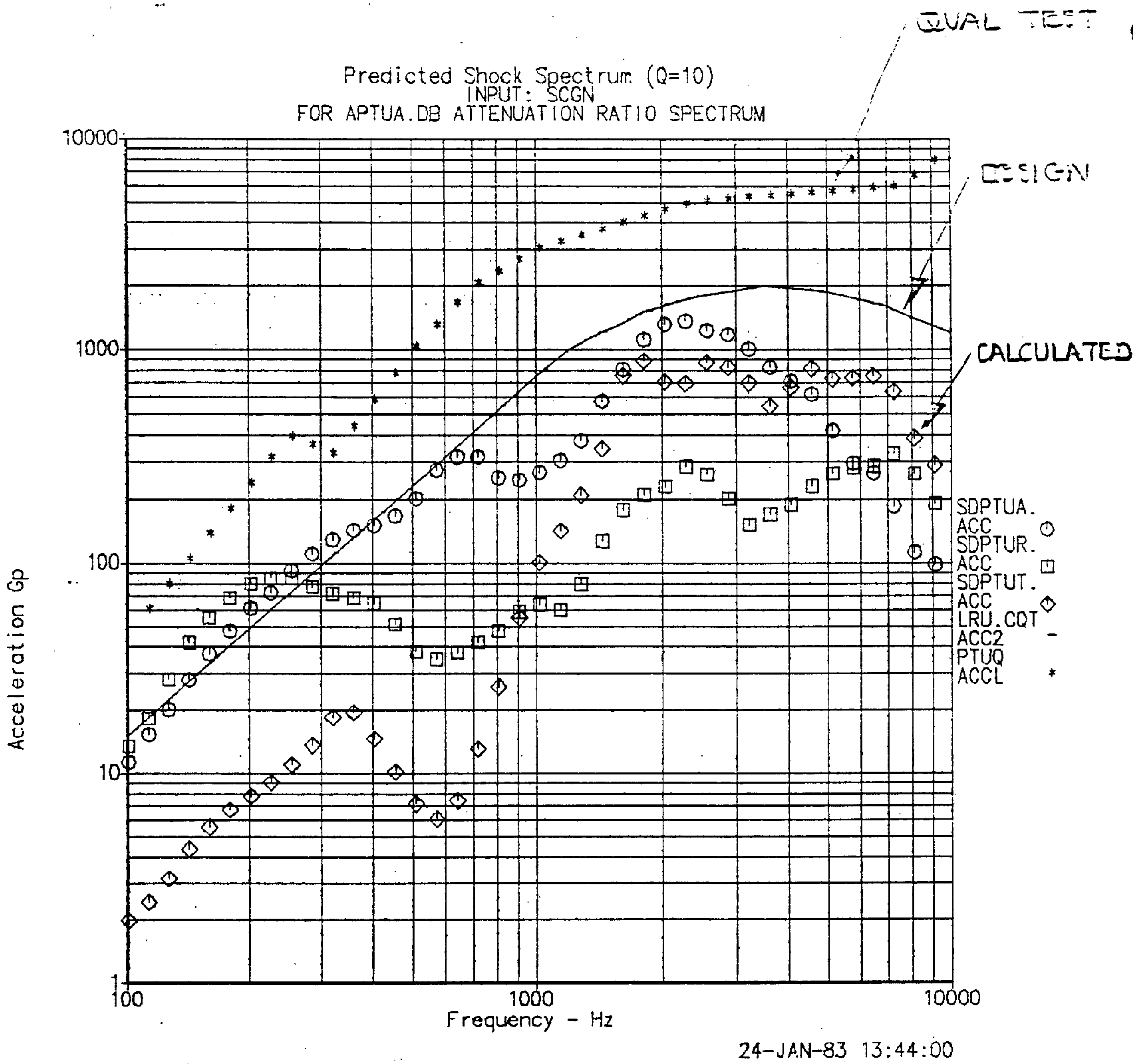

PTU RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS
4 IN. FROM I/F, IUS SIDE

○ Axial
□ Radial
◇ Tangential

CALC	CB	24JAN83	REVISED	DATE	FIGURE 4-25	
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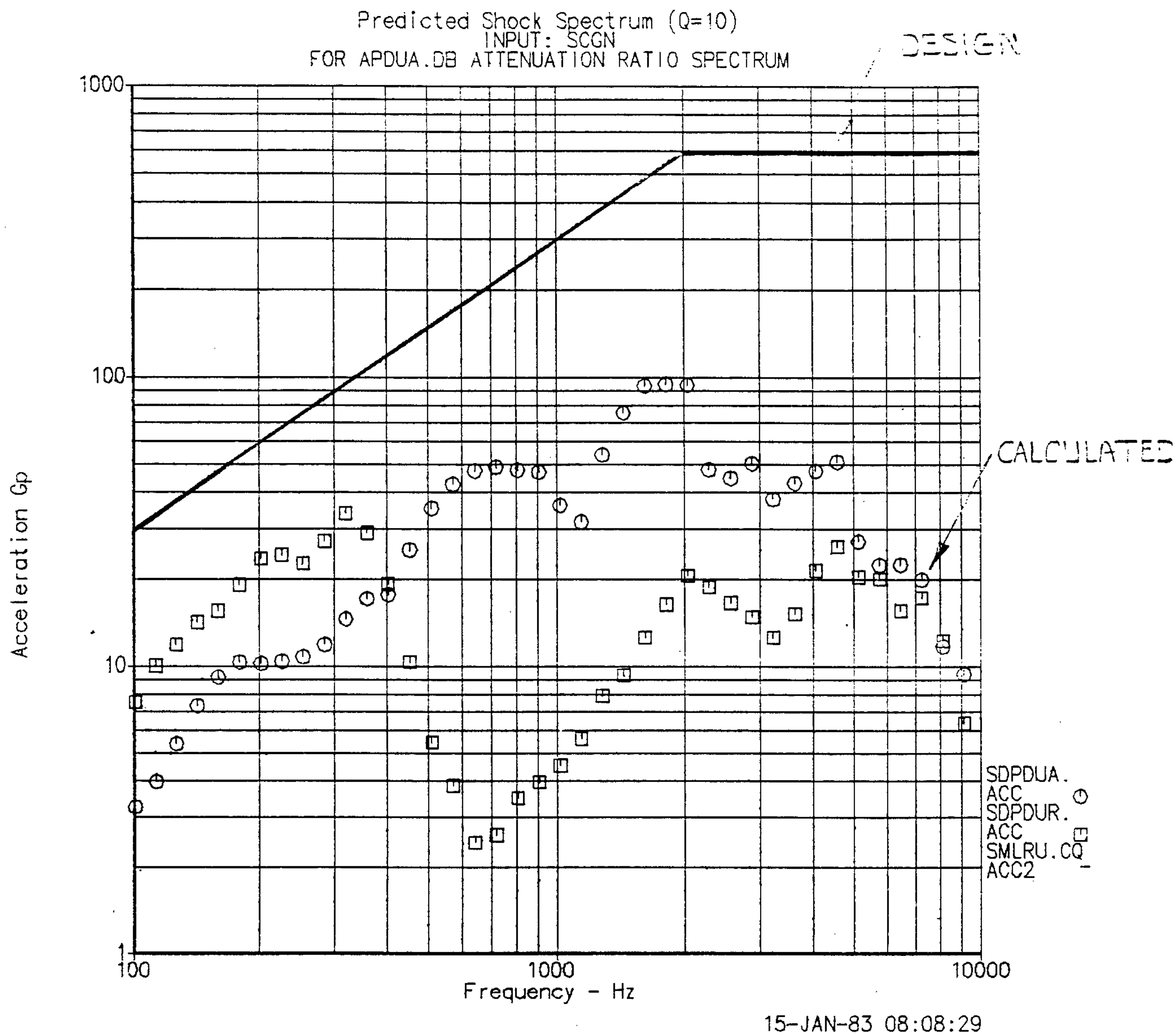

PDU RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS

○ Axial
□ Radial

CALC	TB	15JAN83	REVISED	DATE	FIGURE 4-26	
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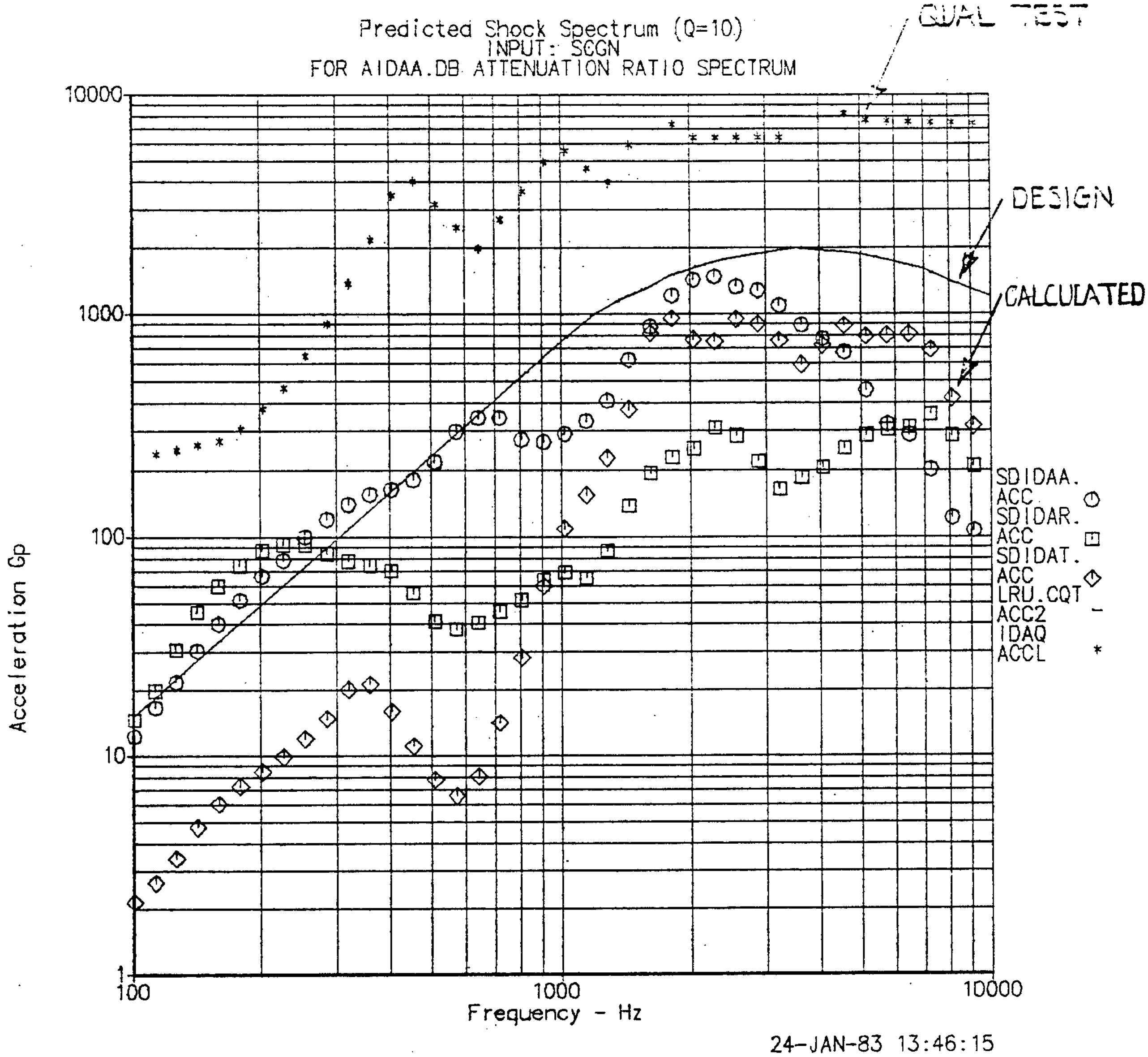

ISOLATION DIODE ASSEMBLY
RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS

○ Axial
□ Radial
◇ Tangential

CALC	CB	24JAN83	REVISED	DATE	FIGURE 4-27
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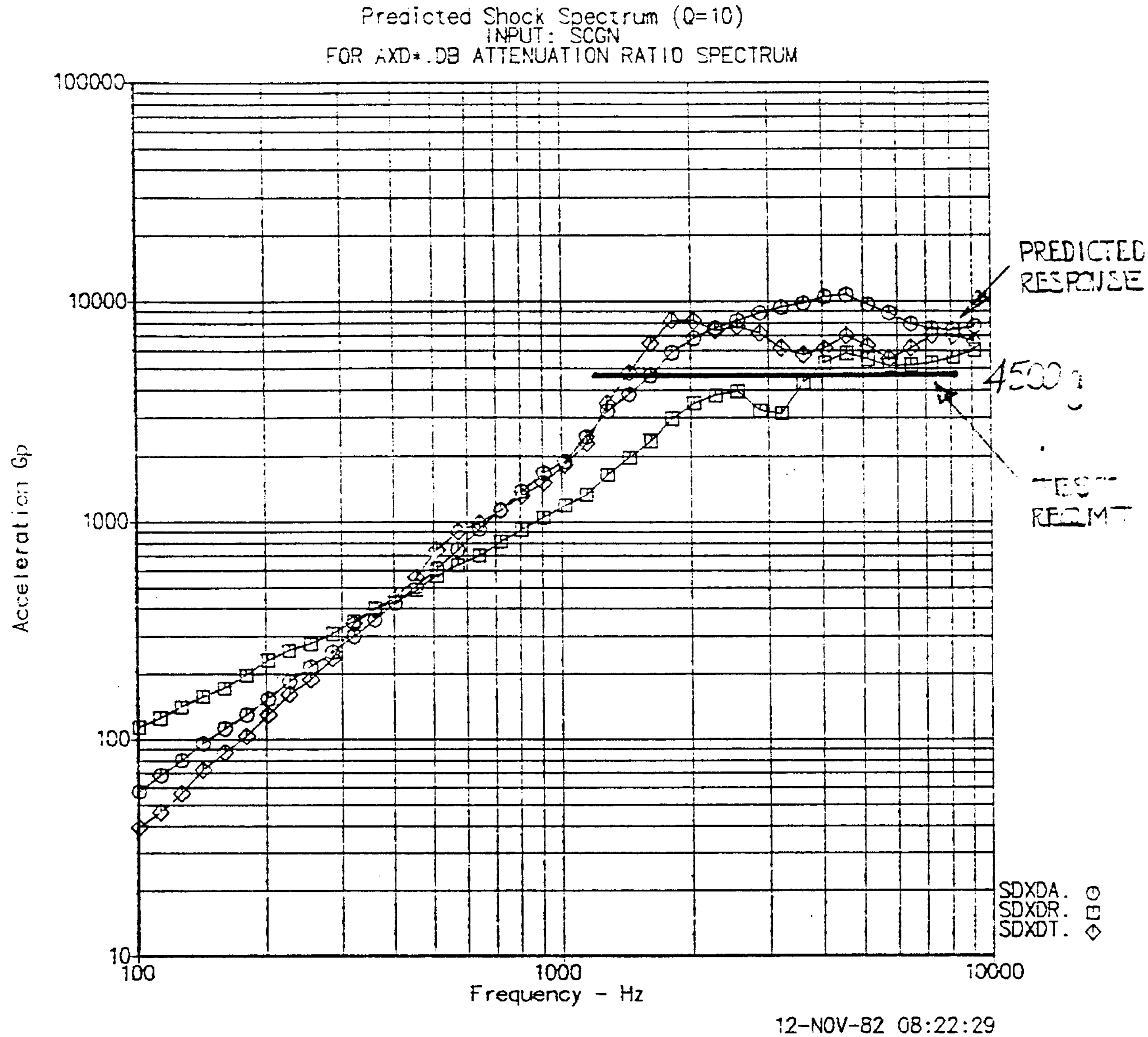

TEMPERATURE SENSOR ASSY
RESPONSE TO
S/C INDUCED SHOCK, PIDS

○ Axial □ Radial ◇ Tangential

CALC	CB	12NOV82	REVISED	DATE	FIGURE 4-28	
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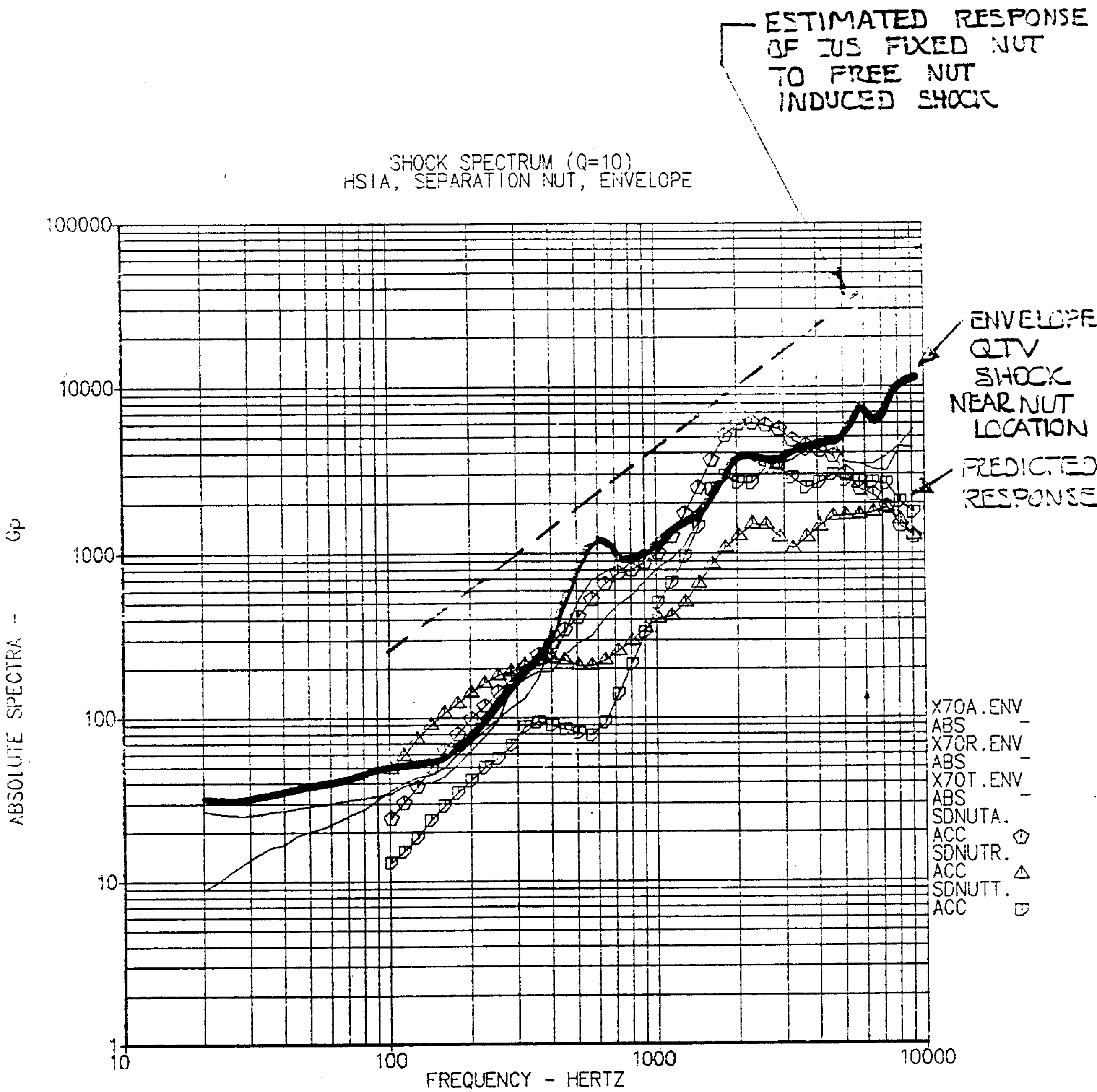

IUS SEPARATION NUT RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

⬠ Axial △ Radial ◻ Tangential

CALC	CJ?	12NOV82	REVISED	DATE	FIGURE 4-29	
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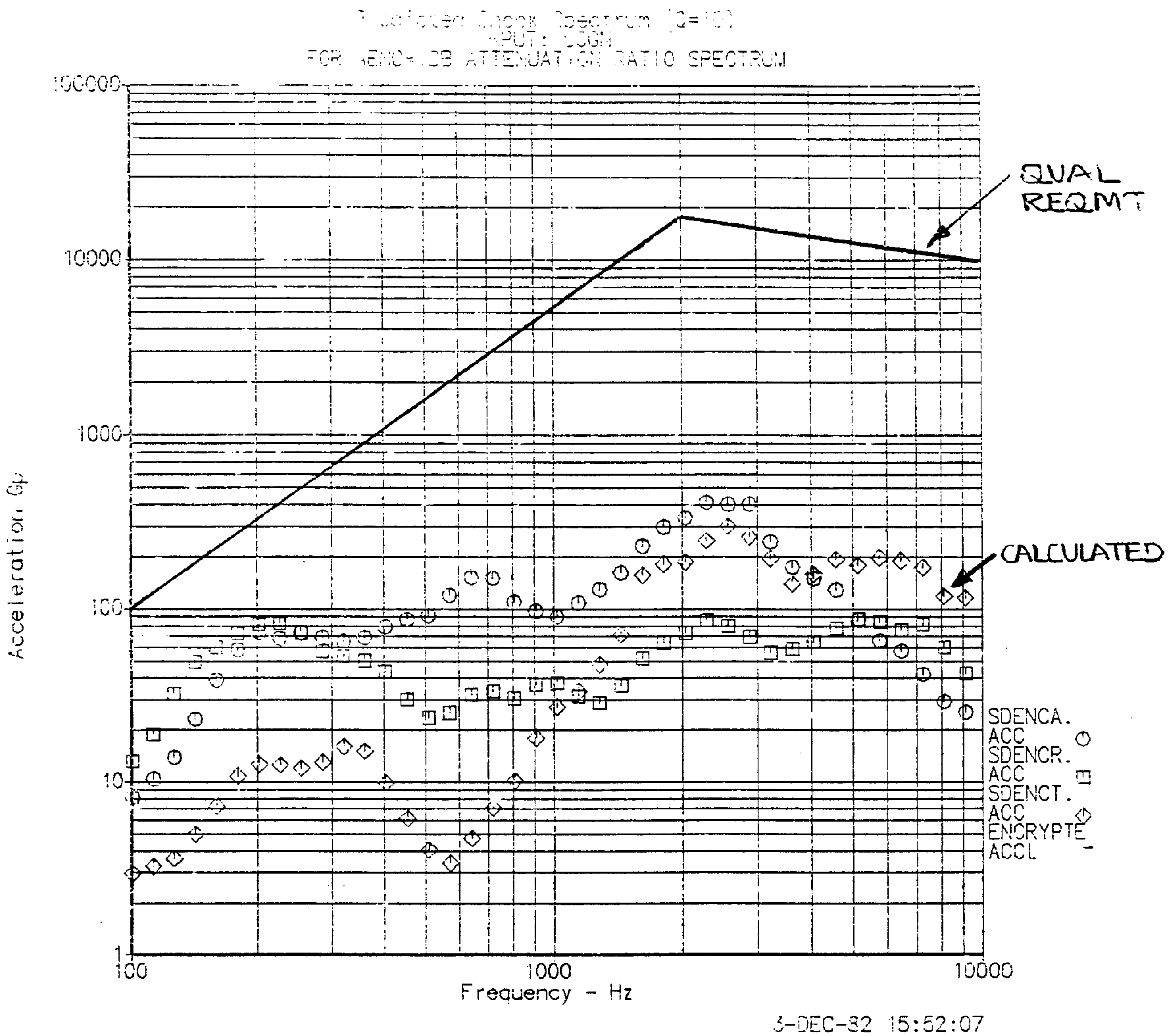

ENCRYPTER RESPONSE TO SPACECRAFT INDUCED SHOCK, PIDS

○Axial □Radial ◇Tangential

CALC	CB	3DEC82	REVISED	DATE	
CHECK					FIGURE 4-30
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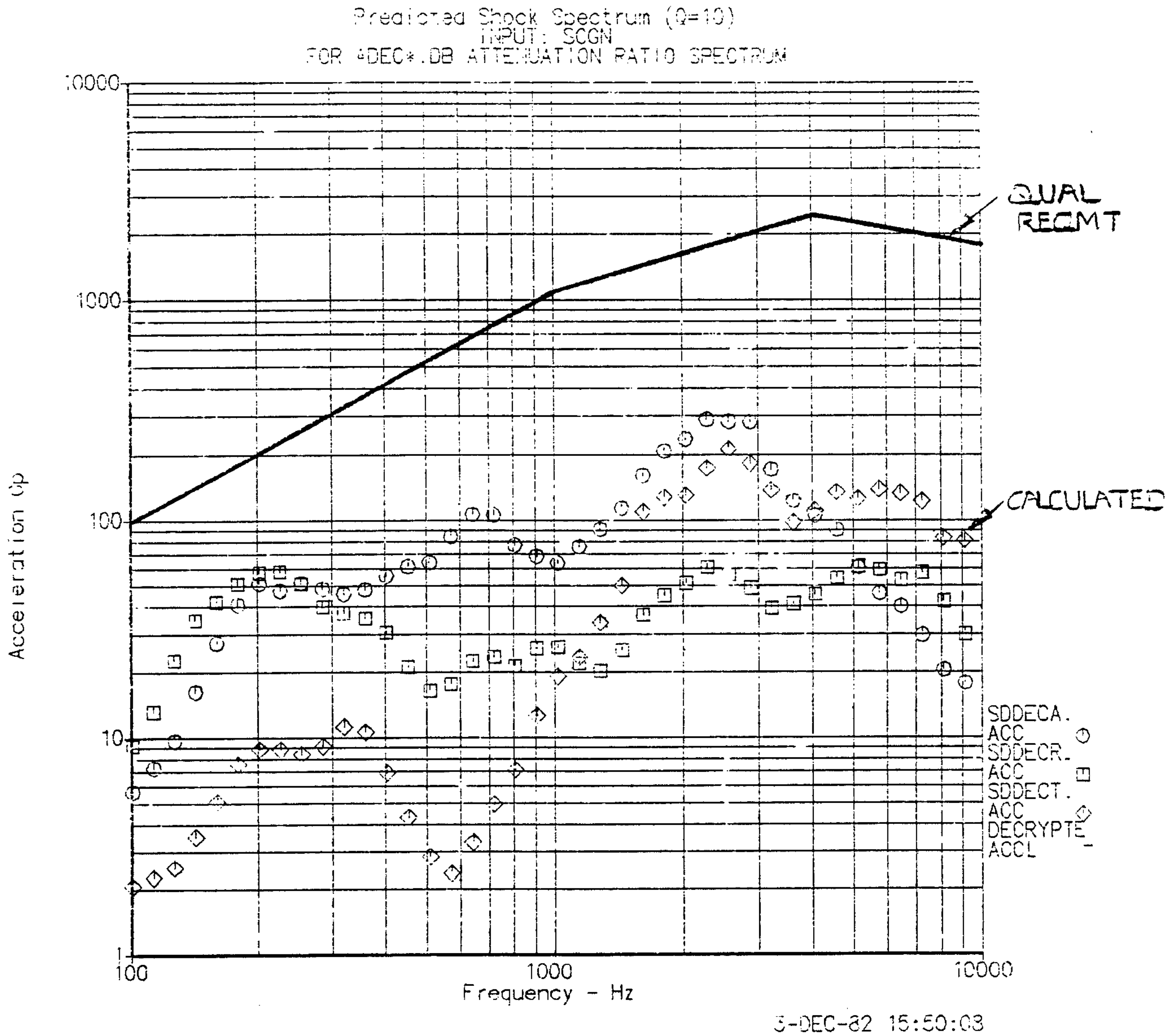
APPD.					THE BOEING COMPANY	PAGE



DECRYPTER RESPONSE TO
SPACECRAFT INDUCED SHOCK, PIDS
O Axial □ Radial ◇ Tangential

CALC	CB	3DEC82	REVISED	DATE	FIGURE 4-31	
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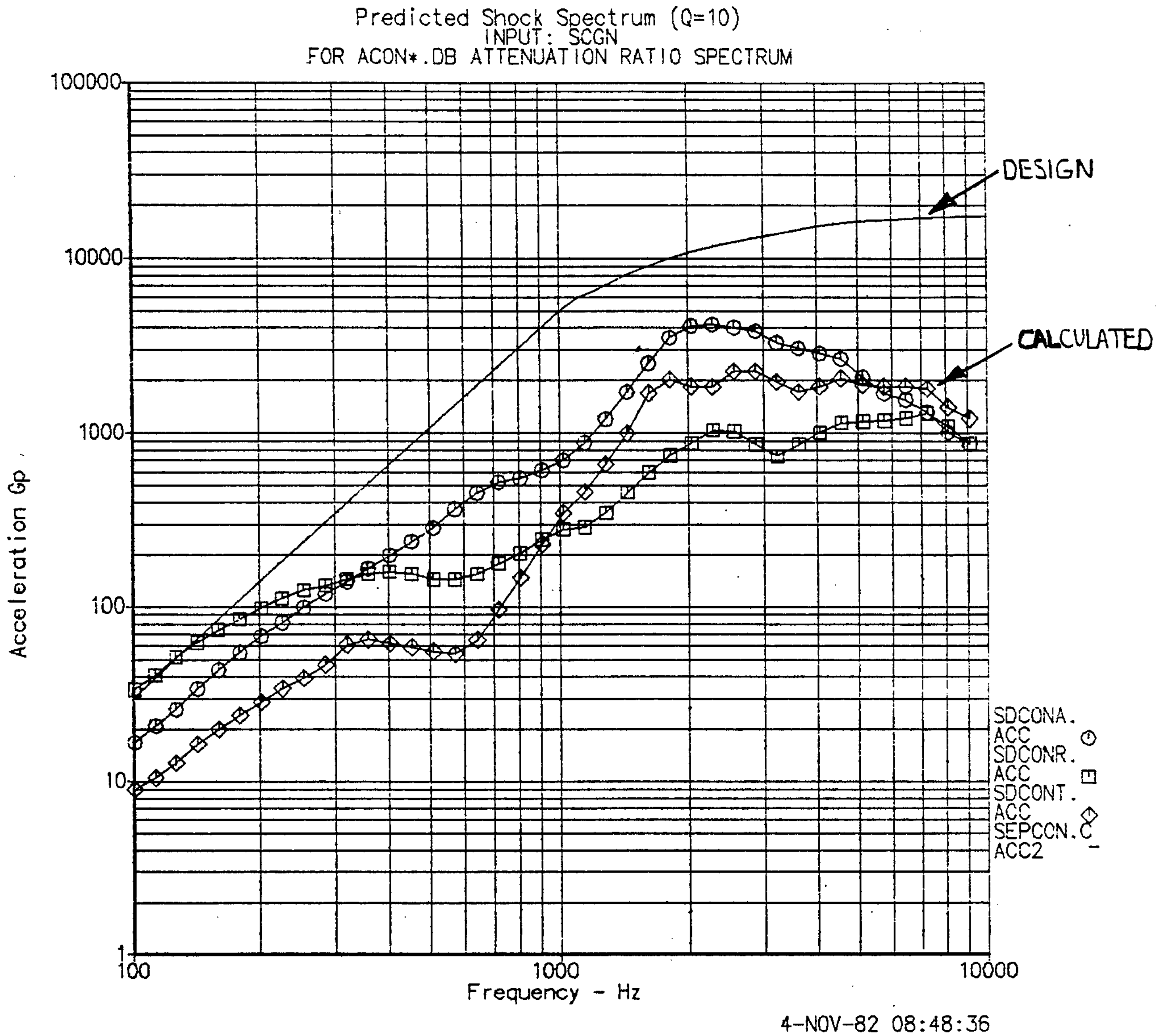

IUS SEPARATION CONNECTOR RESPONSE TO S/C INDUCED SHOCK, PIDS

O Axial
□ Radial
◇ Tangential

CALC	CB	4NOV82	REVISED	DATE	FIGURE 4-32	
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5.0 CONCLUSIONS

1. Thirty-five of the 45 components evaluated are compatible with the spacecraft generated shock, refer to figure 1.

2. Ten of the components have not been qualified to a level 6 db greater than the spacecraft generated shock. These 10 components are:

1. Computer	*6. Med. Gain Antenna*
2. SCU	*7. Diplexer*
3. RF Switch	*8. EMU Transducer*
4. Fail Safe RF Relay	*9. Temperature Sensor*
5. Omni Antenna	*10. Separation Nut*

3. The following components are qualified by analysis. The analyses are presented in paragraphs 5.1 thru 5.8.

1. Computer	*5. Diplexer*
2. SCU	*6. EMU Transducer*
3. Omni Antenna	*7. Temperature Sensor*
4. Med. Gain Antenna	*8. Separation Nut*

4. The RF Switch and the Fail Safe RF Relay will be tested to shock levels which will qualify the components for the spacecraft generated shock. The test levels are discussed in paragraph 5.9.

5.1 Computer Qualification Analysis

The computer response to shock is shown in figure 4-9. The computer is considered to be compatible with the spacecraft shock since the qualification level is low only in a narrow frequency band (about 100 Hz) at 1800 Hz. The qualification level is 3.4 db greater than the calculated response at this frequency.

5.2 SCU Qualification Analysis

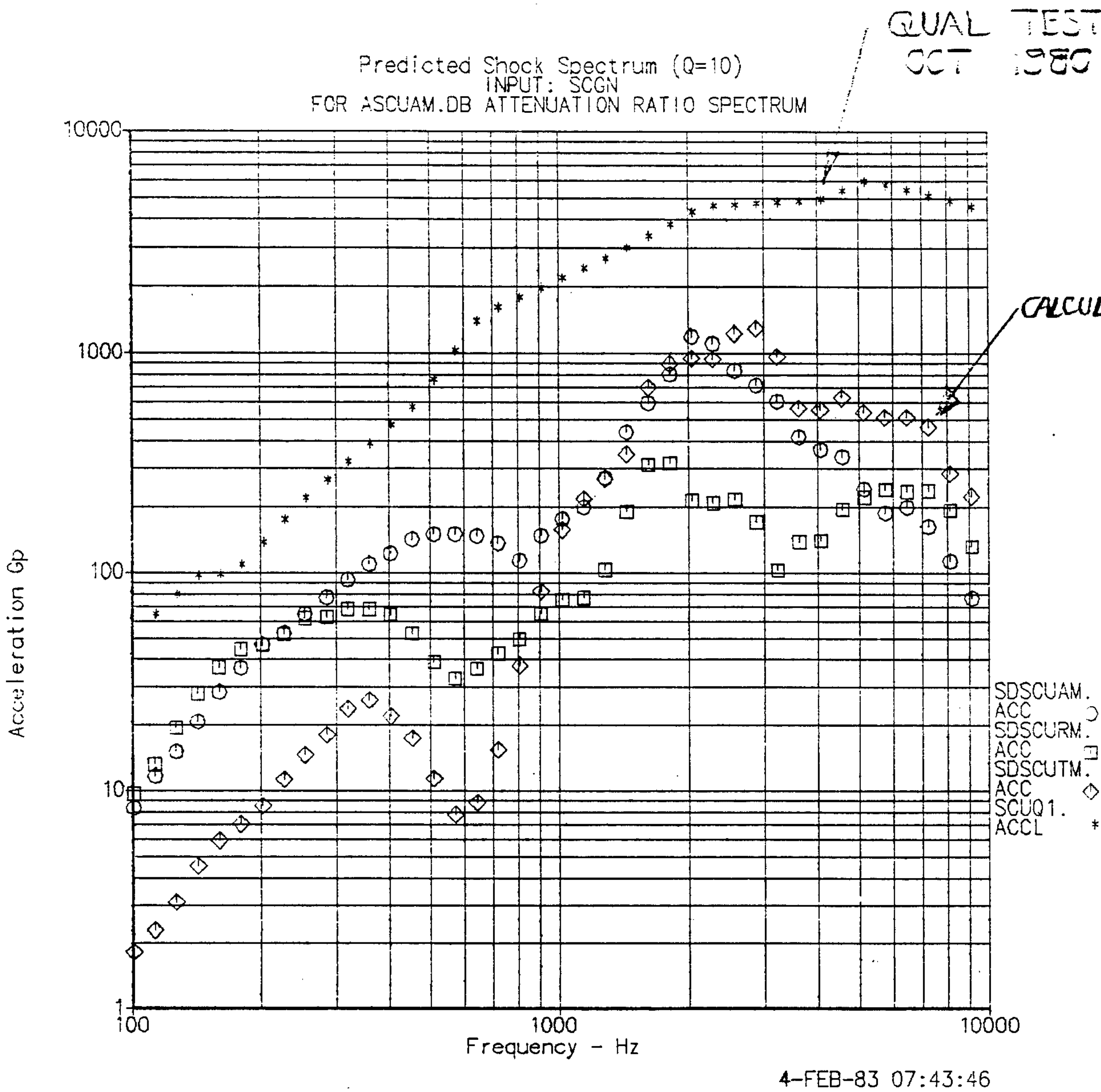
Figure 4-10 shows that the SCU calculated response to spacecraft shock is about the same level as the qualification test level over the frequency range of 2000 to 3000 Hz. The qualification test envelope shown in figure 4-10 is from tests conducted in October 1981, reference 9. The SCU was tested to higher pyro shock levels in October 1980, figure 5-1. The SCU successfully passed the shock tests at the higher levels. Subsequent to the 1980 shock test the SCU sustained mechanical failures in the power supply during random vibration testing. These failures involved screws loosening and backing out and components breaking loose from the printed wire assemblies. Design changes were made to eliminate the cause of these failures. Several electrical circuit design changes were also made subsequent to the 1980 shock tests. The electrical changes resulted in additional cuts and jumpers on the printed wire assemblies. As a result of these changes qualification tests were conducted on the modified SCU in October 1981. Prior to the 1981 tests the shock levels were changed to envelope the levels measured during the IUS QTV stage 1/2 separation tests.

After review of the data in reference 9 and discussions with SCU designers, *it is concluded that the SCU is qualified for the spacecraft induced shock environment*. The rationale for this conclusion follows.

1. The SCU successfully passed pyro shock testing in October 1980 at levels at least 6 db greater than the maximum expected spacecraft induced shock levels, see figure 5-1.

2. The SCU design changes made subsequent to the 1980 tests will not compromise the SCU capability relative to pyrotechnic shock. The mechanical design changes are essentially of two types: (1) cuts and jumpers on the printed wire assemblies; (2) better fastener installation and piece part bonding in the power supply. There were 873 cuts and jumpers distributed among 19 printed wire assemblies in the SCU during the October 1980 shock test. The cuts and jumpers design is considered to be qualified on the basis of the 1980 test. The changes to the power supply were made to eliminate vibration induced failures. A review of these changes indicated that the shock capability of the power supply would not be degraded and would probably result in increased capability. These changes included: applying Conathane CE1155 to all

cover and case screws; use of longer and stronger screws; increased screw torque; improved cleanliness prior to bonding; improved component bonding procedures. The same power supply (HTL K-West S/N 151) was used in the 1980 and 1981 tests.



COMPARISON
SCU RESPONSE TO SC SHOCK, PIDS
VS.
1980 PYRO SHOCK QUAL TEST

CALC		4FEB83	REVISED	DATE	FIGURE 5-1	
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5.3 Medium Gain Antenna Qualification Analysis

The medium gain antenna response to shock is shown in figures 4-15 and 4-16. The response difference is due to the antenna mounting configuration differences between the STS and T34D versions of the IUS (figure 5-2). *The antenna is considered to be compatible with either of the shock environments* for the following reasons.

1. The medium gain antenna is a simple device (figure 5-3) and is not considered to be susceptible to damage by pyrotechnic shock. This conclusion is supported by the requirements of MIL-STD-1540A and 1540B. Both of these documents indicate that component qualification tests of antennas are optional. MIL-STD-1540A states that component acceptance tests of antennas are optional while 1540B does not require antenna acceptance tests.

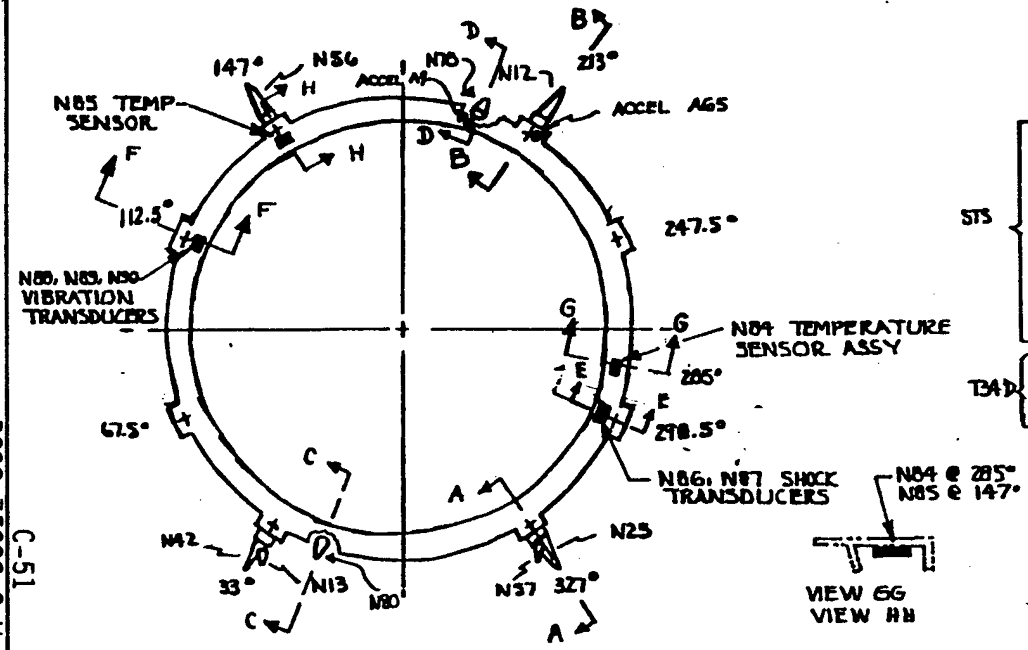
2. If structural damage were to occur to the antenna as a result of shock, it would more than likely occur in the T34D configuration (figure 4-16). Structural damage due to dynamic response generally occurs at lower resonant frequencies. Structural response at the lower frequencies results in higher structural displacements and corresponding larger stresses in the component. This phenomena is illustrated in the following table.

Configuration	*Frequency (Hz)*	*Response (g)*	*Displacement (in. DA)*
T34D	200	200	0.10
T34D	600	1300	0.07
STS	3000	5000	0.01
STS	5000	5000	0.004

At the lower frequencies (below 300 Hz) the medium gain antenna has been subjected to random vibration tests which produced peak g levels higher than the shock qualification tests, figure 5-4.

5.4 Omni Antenna Qualification Analysis

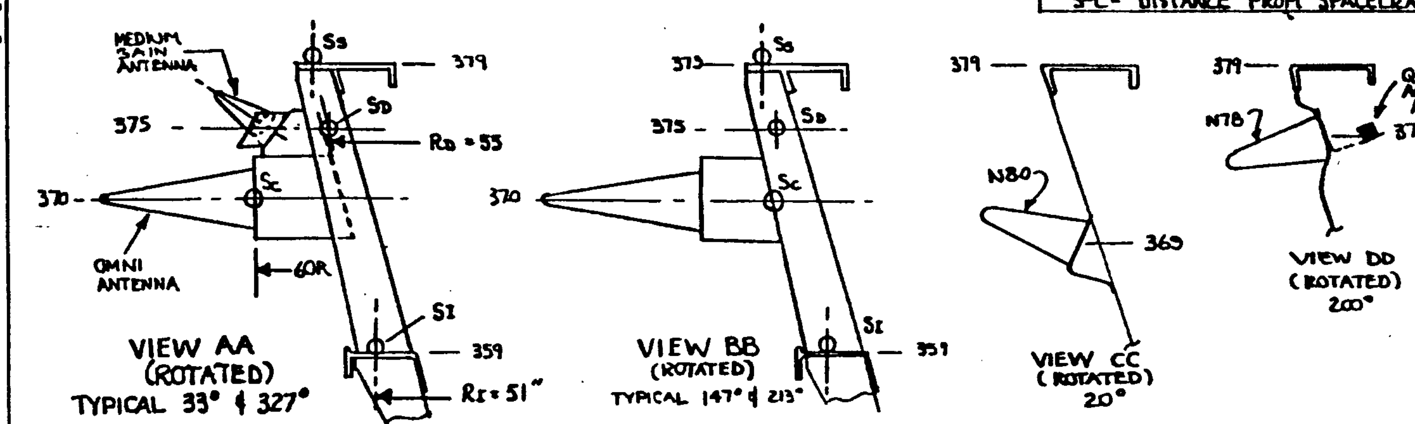
The omni antenna response to shock is shown in figure 4-14. *The omni antenna is compatible with the shock environment* on the basis of the rationale presented in paragraph 5.3. The omni and medium gain antenna similarity is shown in figure 5-3.



	COMPONENT				SOURCE NEAREST COMPONENT						PATH LENGTH / NUMBER OF JOINTS	
		LOCATION			S_I ~ IUS			S_D ~ S/C				
ID.	NAME	X_C	θ_C	R_C	X_I	θ_I	R_I	X_D	θ_D	R_D	I-C	S-C
N12	OMNI ANTENNA	370"	213°	60"	359"	213°	51	379"	213°	55"	17/1	15/2
N13	MED. GAIN ANT.	375	33	60	↓	33	↓	↓	33	↓	21"/1	8/2
N25	OMNI ANT.	370	327	60"	↓	327	↓	↓	327	↓	17/1	15/2
N42	OMNI ANT.	370	33°	60	↓	33	↓	↓	33	↓	17/1	15/2
N56	OMNI ANT.	370	147°	60	↓	147	↓	↓	147	↓	17/1	15/2
N57	MED. GAIN ANT.	375	327	60	↓	327	↓	↓	327	↓	21/1	8/2
N78	MED. GAIN. ANT.	375	200	50	↓	213	↓	↓	213	↓	37/1	16/1
N80	MED. GAIN ANT.	369	20	50	↓	33°	↓	↓	33	↓	42/1	22/1
N86	SHOCK ACCEL.	379	290.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1
N87	SHOCK ACCEL	379	290.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1
N88	VIB TRANSDUCER	379	112.5	52	↓	112.5	↓	↓	112.5	↓	22/2	2/1
N89	" "	379	112.5	↓	↓	"	↓	↓	"	↓	"	"
N90	" "	379	112.5	↓	↓	"	↓	↓	"	↓	"	"
N84	TEMP SENSOR	379	285	↓	↓	292.5	↓	↓	292.5	↓	27/2	2/0
N85	" "	379	147	↓	↓	147	↓	↓	147	↓	22/2	3/0

STS: N12–N57; T34D: N78–N80

I-C = DISTANCE FROM IUS SEPARATION NUT TO COMPONENT
S-C = DISTANCE FROM SPACECRAFT ATTACH POINT TO COMPONENT



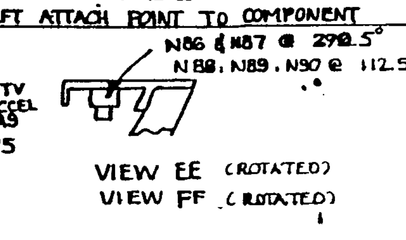
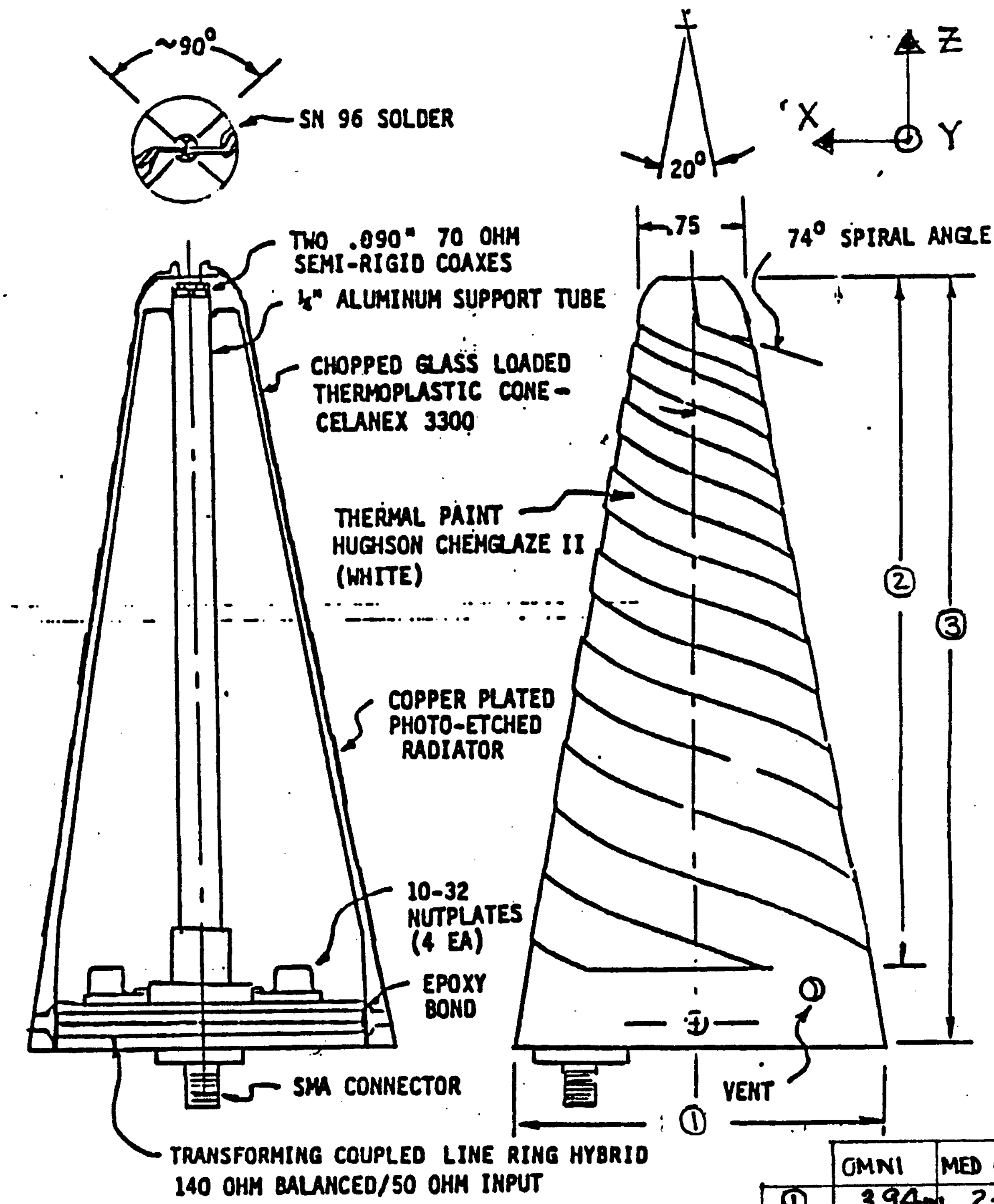


FIGURE 5-2
SHOCK PATHS
ANTENNAS
VIBRATION & SHOCK TRANSDUCERS
TEMPERATURE SENSORS

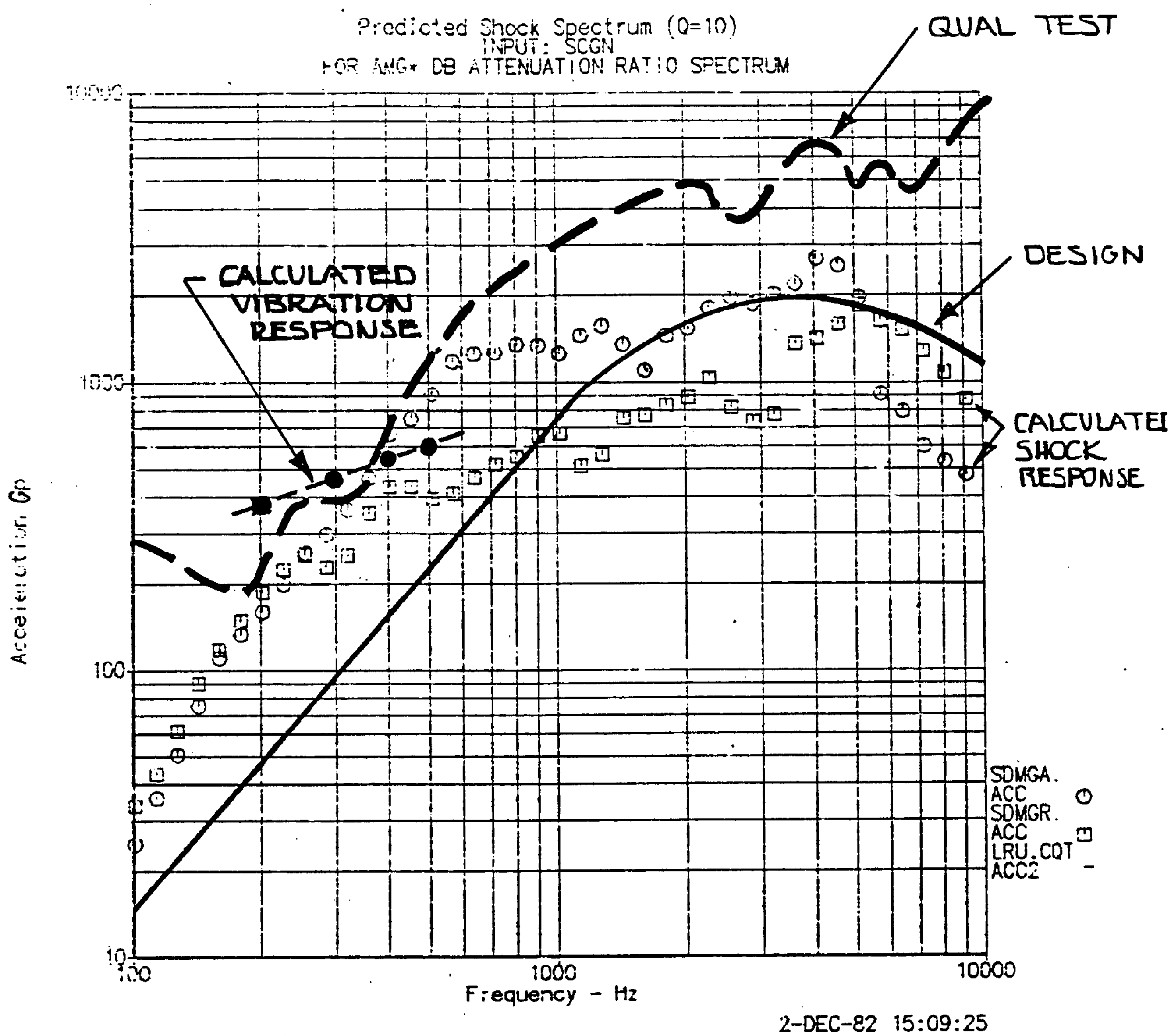
CBeck 2/8/83



	OMNI	MED GAIN
①	3.94 IN	2.43 IN
②	9.7	4.58
③	10.2	5.08

Medium Gain Antenna shown, Omni Antenna construction similar

FIGURE 5-3 ANTENNA CONSTRUCTION



MEDIUM GAIN ANTENNA
RESPONSE TO
(1) SPACECRAFT INDUCED SHOCK, PIDS
(2) RANDOM VIBRATION QUAL TEST
T34 D CONFIGURATION

O Axial □ Radial

CALC	GS	2DEC82	REVISED	DATE	FIGURE 5-4
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5.5 Diplexer Qualification Analysis

The diplexer response to shock is shown in figure 4-19. *The diplexer is considered to be compatible with the spacecraft shock* since the qualification level is low only in the 200 Hz to 350 Hz frequency range. The margin is at least 2 db in this range.

5.6 EMU Transducer Qualification Analysis

The EMU transducer response to shock is shown in figure 4-21. A shock transducer and vibration transducer are included as part of the environmental measurement unit subsystem. The transducer locations are shown in figure 5-2. *The shock transducer is compatible with the spacecraft induced shock.* The vibration transducer has not been qualified to a high enough level to demonstrate compatibility with the shock environment. Although compatibility of the vibration transducer has not been demonstrated by test, *the transducer is considered to be compatible with the shock environment* for the following reasons.

1. The purpose of the vibration transducer is to measure vibration levels on the IUS. The significant levels occur prior to IUS separation from the launch vehicle. The maximum spacecraft induced shock levels occur at the time of spacecraft separation. Therefore, the most important aspects of the vibration environment will have been measured prior to spacecraft separation shock.

2. Piezoelectric vibration transducers of the type used on IUS are inherently rugged devices which in all probability have the capability of surviving the spacecraft shock.

5.7 Temperature Sensor Qualification Analysis

The temperature sensor assembly response to shock is shown in figure 4-28. The locations of the sensors on the IUS are shown in figure 5-2. Although the temperature sensor has not been qualified by test to levels 6 db higher than the predicted shock environment, *the sensor is expected to perform adequately during the IUS mission* for the following reasons.

1. The purpose of the sensors is to provide the temperature at the spacecraft interface. The temperature data is not required after spacecraft separation. Therefore, it is not necessary to demonstrate that the sensor will operate during or after the separation shock.

2. The shock levels generated on the temperature sensor during the IUS QTV stage 1/2 separation test are considered to be of sufficient severity to demonstrate the structural integrity of the sensor-to-structure attachment.

5.8 Separation Nut Qualification Analysis

Figure 4-29 shows the IUS stage 1/2 separation nut response to the spacecraft separation shock. The prediction is compared to the shock measured about 4 inches from the IUS separation nuts when the IUS nuts were fired during the QTV stage 1/2 separation tests.. Since the IUS separation system consists of 2 separation nuts (figure 5-5), the fixed nut is required to survive the shock from the free separation nut and then fire to eject the separation stud. The shock delivered to the IUS fixed nut by the free nut is estimated to be significantly higher than the spacecraft induced shock as shown in figure 4-29. The ability of the fixed nut to survive and function following the free nut shock has been demonstrated during the QTV stage 1/2 separation tests. Therefore, *the IUS separation nuts are considered to be compatible with the spacecraft shock.*

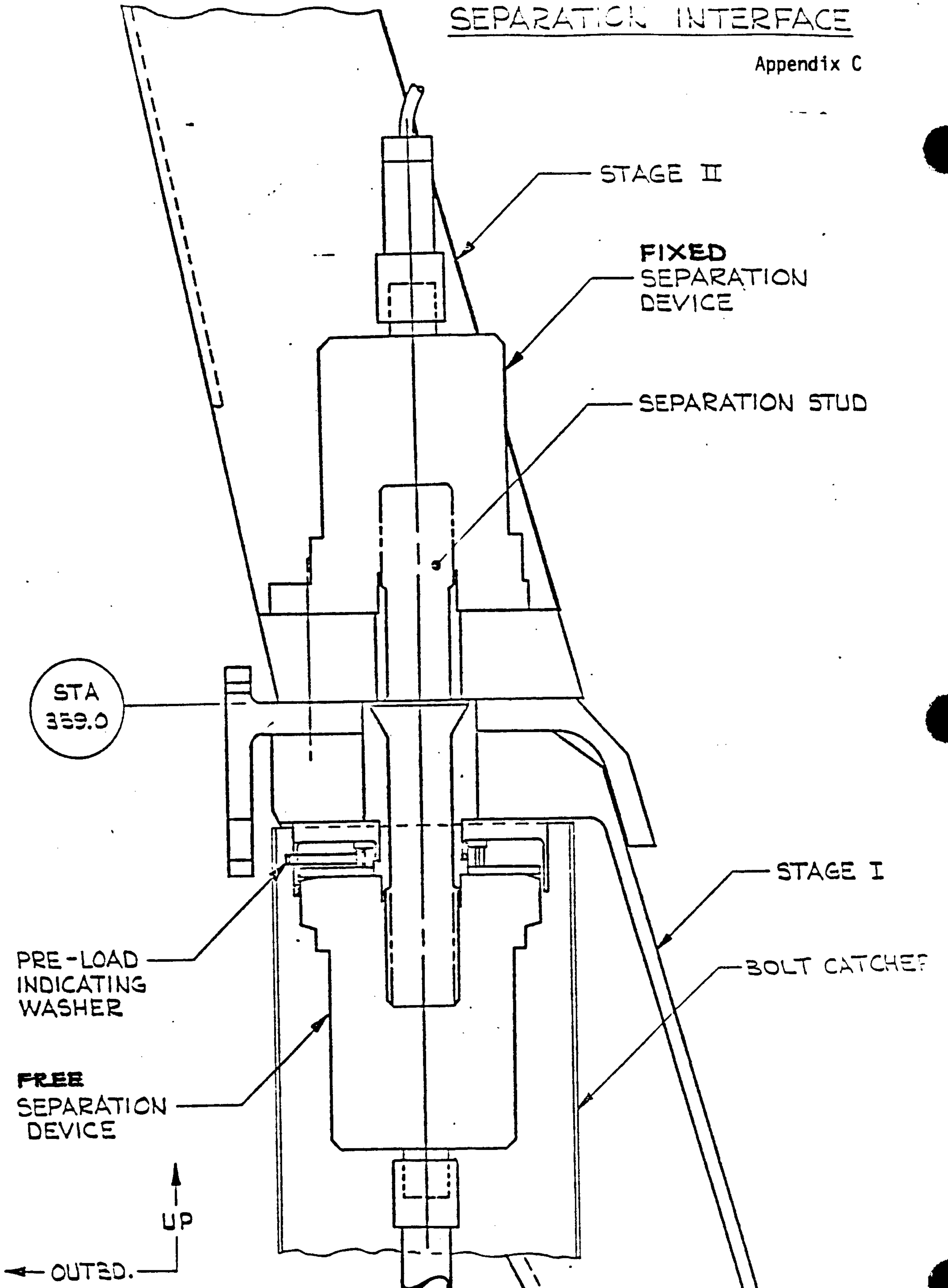
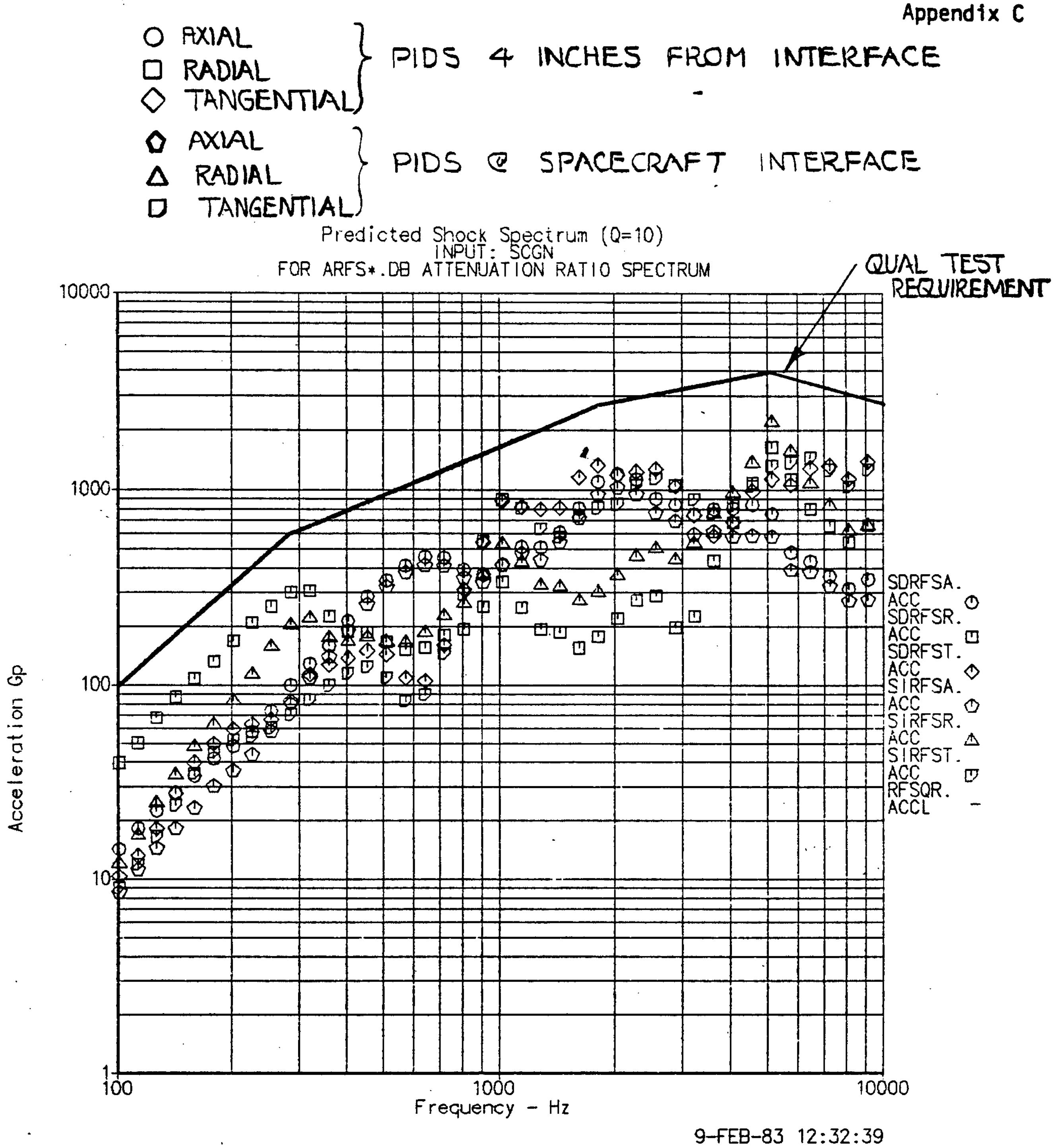


FIGURE 5-5 IUS SEPARATION SYSTEM

5.9 Qualification Test Levels, RF Switch and Fail Safe RF Relay

The RF switch and fail safe RF relay will be qualification tested to higher levels. The qualification levels will be 6 db greater than the calculated response to spacecraft generated separation shock. The spacecraft shock was calculated assuming the PIDS level applied at a point 4 inches from the interface and at the point where the spacecraft attachs to the IUS. The qualification test spectrum is shown in figure 5-6.



QUALIFICATION TEST REQUIREMENT
RF SWITCH
FAIL SAFE RF RELAY
VS.
RFSWITCH & FAIL SAFE RF RELAY
RESPONSE TO SPACECRAFT INDUCED SHOCK

CALC	GB	9FEB83	REVISED	DATE	FIGURE 5-6
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6.0TRANSFER FUNCTION CALCULATIONS

The transfer functions (TF) used to calculate the response of IUS components to the spacecraft generated shock are based on data from the IUS QTV stage1/2 separation test. The QTV data and transfer function equations have been discussed in previous analyses, references 6, 7 and 8. This section summarizes the transfer functions for the analyses in this document. Transfer functions which have changed from previous analyses are identified and the changes are discussed. The TFs are identified by file names used in the VAX computer. An interpretation of the file names is provided.

Transfer Functions Used

Figure 6-1 lists the IUS components and transfer functions used to calculate the IUS component response to the spacecraft generated shock. Column 1 contains the name of the VAX computer files which describe the transfer function. The transfer functions were calculated by adding the various attenuations along the shock path. The attenuation functions associated with each transfer function are listed in column 2. The attenuation function codes of column 2 are defined in figure 6-2. The attenuation function spectra are shown in figures 6-3 thru 6-21. Column 3 contains the VAX computer file names containing the calculated component response to spacecraft generated shock.

Transfer Function Changes

Previous analyses (references 6, 7 and 8) were based on spacecraft generated shock measured on the spacecraft. The analyses in this document are based on the spacecraft generated shock defined in the PIDS. The PIDS defines the spacecraft shock at a point on the IUS 4 inches from the IUS spacecraft interface (IUS station 375)..Therefore, *all attenuation transfer functions were calculated between a point on an IUS ESS longeron at station 375 and the component location*.

Previous analyses of the REM and the Medium Gain Antenna used the attenuation between the spacecraft and the component, A2 and A15, as one part of the transfer function. The analyses contained in this report use the attenuation between the IUS separation nut and the component, A17 or A18, in place of A2 or A15. This change was made because the spacecraft attach point was not the source of the shock for the QTV test. Also, for the components involved (REM, Medium Gain Antenna and SRM2 Safe and Arm) the distances from the IUS separation nut and the spacecraft attach point are similar.

Previous analyses of the SRM2 Safe and Arm Device were based on the envelope of spectra from test numbers 1,2 and 3 for accelerometer 8 located on the isolated side of the S & A. For the analysis in this document the transfer function is based on the output from accelerometer 8 recorded during separation test number 1 conducted on 18 May 1981. The spectra from test numbers 2 and 3 were judged to be invalid.

Previous ananlyses of the SCU were based on the average ESS deck transfer function with a correction for distance of the component relative to the average component distance from the shock source. For the analysis in this document the SCU transfer function is based on the response of the accelerometer located closest to the SCU (accelerometer 11). Similarly, the star scanner transfer function is based on the response of accelerometer 19.

FIGURE 6-1 TRANSFER FUNCTIONS

COMPONENT	COLUMN 1	COLUMN 2	COLUMN 3
Safe & Arm, SRM-1 (Stage 1)	None	None	None
Safe & Arm, SRM-2	ASA*.DB	M1, A18, A19	SDSA.GGP
REM	AREM*.DB	M1, A17	SDREM.GGP
RCS Manifold	None	None	None
RCS Tank Module Assy	ARCS*.DB	A10, A12, AB = −2.5	SDRCS.GGP
Resistor Board Assy	ARCS*.DB	A10, A12, AB = −2.5	SDRCS.GGP
Star Scanner	ASS*M.DB	A10, A21	SDSSM.GGP
Inertial Meas. Unit	AIMU*.DB	A10, A12, AB = 3.9	SDIMU.GGP
TVC Actuator	ATVCP*.DB	A10, A12, AB = 18.3	SDTVCP.GGP
TVC Controller	ATVCC*.DB	A9, A10, AB = −0.5	SDTVCC.GGP
TVC Potentiometer	ATVCP*.DB	A10, A12, AB = 18.3	SDTVCP.GGP
Computer, Central Avion.	ACP*.DB	A3, A4	SDCP.GGP
Signal Cond. Unit (SCU) and Code Plug, SCU	ASCU*M.DB	A10, A20	SDSCUM.GGP
Signal Interface Unit (SIU)	ASIU*.DB	A9, A10, AB = −2.2	SDSIU.GGP
Titan Interface Unit (TIU)	ATIU*.DB	A10, A12,A13, AB = −0.6	SDTIU.GGP
RF Switch (2 pole)	ARFS *.DB	M1, A14, AB = −0.6	SDRFS.GGP

Notes
Column 1 Transfer function file name (VAX computer)
Column 2 Attenuation functions used to calculate Transfer functions, see figure 6-2.
Column 3 Calculated shock spectra file name (VAX computer).
* Direction: axial (A), radial (R), tangential (T)

FIGURE 6-1 TRANSFER FUNCTIONS

COMPONENT	COLUMN 1	COLUMN 2	COLUMN 3
Antenna, Omni, DOD	AANT*.DB	AB = 3.0	SDANT.GGP
Antenna, Med. Gain	AMG *.DB	M1, A18	SDMG.GGP
SGLS Transponder, S Band	AXPON*.DB	A9, A10, AB = −4.8	SDXPON.GGP
20 Watt Amplifier, S Band	APA*.DB	A5, A6	SDPA.GGP
Diplexer (DOD)	ADIP*.DB	M1, A14	SDDIP.GGP
Environ. Meas. Subsystem	AEMU*.DB	A9, A10, AB = −2.5	SDEMU.GGP
EMU Transducers	AXD*.DB	M1	SDXD.GGP
Fail Safe R/F Relay	ARFS*.DB	M1, A14, AB = −0.6	SDRFS.GGP
DC Block (Stage 1)	None	None	None
Avionics Battery (140 AH) (Stage 1)	None	None	None
Utility Battery (13 AH)	ABAT*.DB	A10, A11	SDBAT.GGP
Avionics/Spacecraft Battery (100 AH) (Stage 1)	None	None	None
Avionics Battery (170 AH, Stage 1)	None	None	None
T34D/IUS Destruct Battery	None	None	None
DC/DC Converter Regulator	ADC*.DB	A7, A8	SDDC.GGP
Pyro Switching Unit (PSU)	APSU*.DB	A10, A12, AB = −0.6	SDPSU.GGP
Power Transfer Unit (PTU)	APTU*.DB	A10, A12, AB = −1.8	SDPTU.GGP

Notes

Column 1 Transfer function file name (VAX computer)

Column 2 Attenuation functions used to calculate Transfer functions, see figure 6-2.

Column 3 Calculated shock spectra file name (VAX computer)..

* Direction: axial (A), radial (R), tangential (T)

FIGURE 6-1 TRANSFER FUNCTIONS

COMPONENT	COLUMN 1	COLUMN 2	COLUMN 3
Power Distributor Unit (PDU)	APDU *.DB	A10, A12, A13, AB = −3.2	SDPDU.GGP
Isolation Diode Assy	AIDA*.DB	A10, A12, AB = −2.5	SDIDA.GGP
Temperature Sensor Assy	AXD*.DB	M1	SDXD.GGP
Separation Nuts	HSIHSL*.DB	A10	SDNUT.GGP
Staging Mech. (Super Zip, Stage 1)	None	None	None
T34D/IUS Destruct System	None	None	None
T34D/IUS Safe and Arm	None	None	None
Encryptor (KG-46)	AENC*.DB	A9, A10, AB = −4.8	SDENC.GGP
Decryptor (KIR-23)	ADEC*.DB	A9, A10, AB = −1.7	SDDEC.GGP
EEC	None	None	None
Staging Connector	ACON*.DB	A10, AB = 3.2	SDCON.GGP
Pyro Connector (Stage 1)	None	None	None

Notes
Column 1 Transfer function file name (VAX computer)
Column 2 Attenuation functions used to calculate Transfer functions, see figure 6-2.
Column 3 Calculated shock spectra file name (VAX computer)..
* Direction: axial (A), radial (R), tangential (T)

FIGURE 6-2 ATTENUATION FUNCTIONS

M1 = HSSHSL*.DB **Figure 6-3**
The inverse attenuation across the joint between the IUS ESS longeron and IUS 379 ring. This function is used to calculate the spacecraft generated shock existing at the IUS/spacecraft interface since the PIDS defines the spacecraft shock at a point 4 inches on the IUS side of the interface.

A1 = HSLHSS*.DB **Figure 6-3A**
Attenuation across the joint between the IUS ESS longeron and IUS 379 ring.

A2 = HSSH04*.DB **Figure 6-4**
Attenuation between the spacecraft attach point and the IUS REM located 26.6 inches from the attach point.

A3 = HSIHCI*.DB **Figure 6-5**
Attenuation between the IUS stage 1/2 separation nut and the computer isolator input.

A4 = HCIH05A.DB and HCI H71R.DB **Figure 6-6**
Attenuation across the computer isolator.

A5 = X70H76*.DB **Figure 6-7**
Attenuation between the IUS stage 1/2 separation nut and the power amplifier isolator input.

A6 = HPIHPO*.DB **Figure 6-8**
Attenuation across the power amplifier isolator.

A7 = HSIDCI*.DB **Figure 6-9**
Attenuation between the IUS stage 1/2 separation nut and the DC-DC converter isolator input.

A8 = DCIDCO*.DB **Figure 6-10**
Attenuation across the DC-DC converter isolator.

A9 = HSIHIC*.DB **Figure 6-11**
Attenuation between the IUS stage 1/2 separation nut and a location on the inner conic (40 inch shock path).

A10 = HSIHSL*.DB **Figure 6-12**
Attenuation between the IUS stage 1/2 separation nut and the top of the ESS longeron (16 inch shock path).

A11 = X70H07*.DB **Figure 6 -12A**
Attenuation between the IUS stage 1/2 separation nut and the ESS battery support (21 inch shock path).

A12 = HSIHED*.DB **Figure 6-13**
Attenuation between the IUS stage 1/2 separation nut and the ESS deck (16 inch shock path).

A13 = HUIHUO*.DB **Figure 6-14**
Attenuation across the PDU isolator.

FIGURE 6-2 ATTENUATION FUNCTIONS (CONTINUED)

A14 = HSIH44*.DB **Figure 6-15**
Attenuation between the IUS stage 1/2 separation nut and the RF switch support (40 inch shock path).

A15 = H65H09*.DB **Figure 6-16**
Attenuation between spacecraft attach point and SRM 2 safe and arm isolator.input (30 inch shock path).

A17 = HSIH04*.DB **Figure 6-17**
Attenuation between the IUS stage 1/2 separation nut and REM location (30 inch shock path).

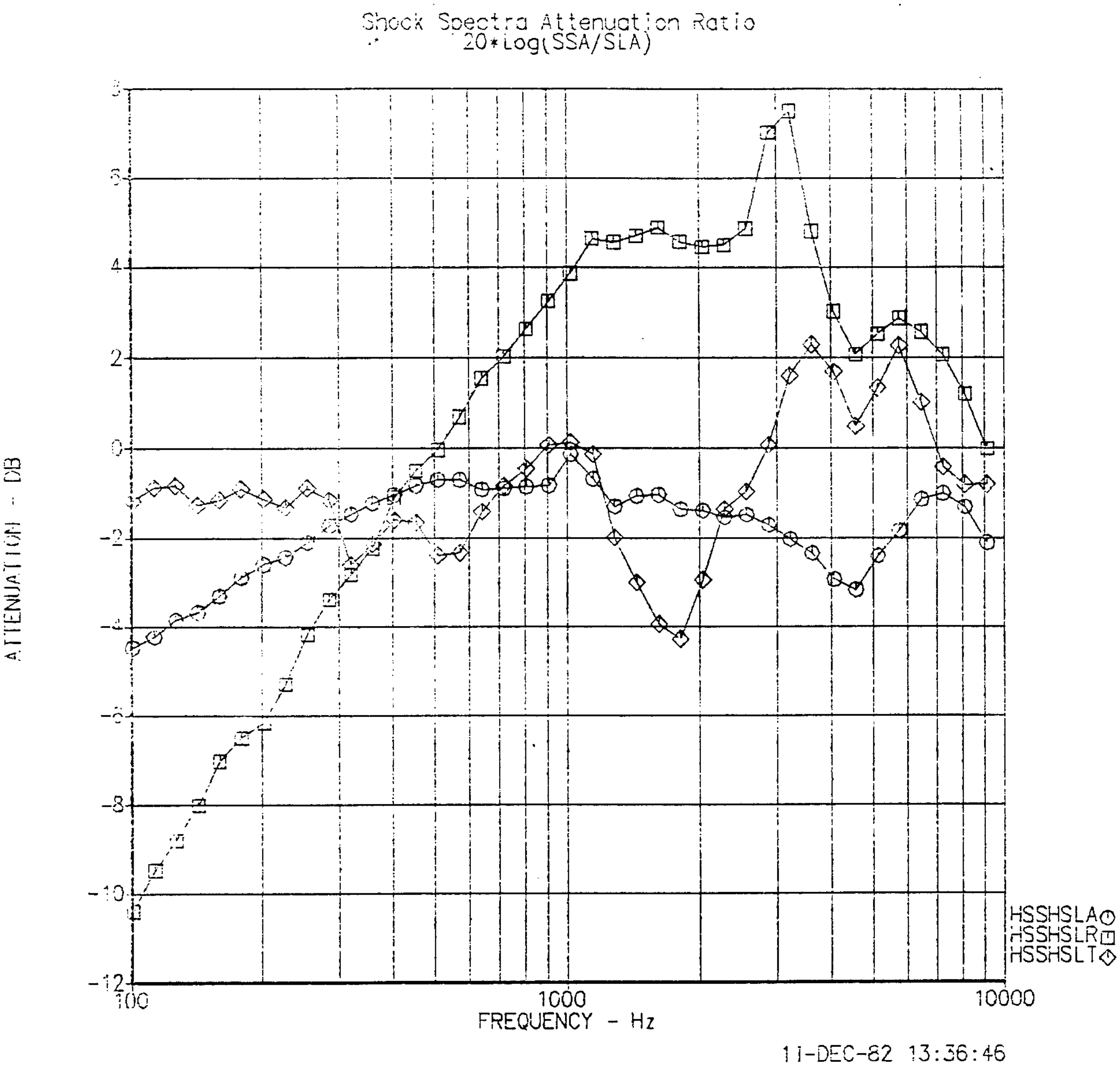
A18 = HSIH09*.DB **Figure 6-18**
Attenuation between the IUS stage 1/2 separation nut and SRM 2 safe and arm (30 inch shock path).

A19 = H09H08*.DB **Figure 6-19**
Attenuation across the safe and arm isolator.

A20 = HSIH11*.DB **Figure 6-20**
Attenuation between the IUS stage 1/2 separation nut and the SCU (8 inch shock path).

A21 = HSIH19*.DB **Figure 6-21**
Attenuation between the IUS stage 1/2 separation nut and the Star Scanner (8 inch shock path).

AB = Variable
Attenuation due to distance , assumes attenuation linear with distance.



M1 = HSSHSL*.DB **Figure 6-3**

The inverse attenuation across the joint between the IUS ESS longeron and IUS 379 ring. This function is used to calculate the spacecraft generated shock existing at the IUS/spacecraft interface since the PIDS defines the spacecraft shock at a point 4 inches on the IUS side of the interface.

CALC		11DEC82	REVISED	DATE	FIGURE 6-3	
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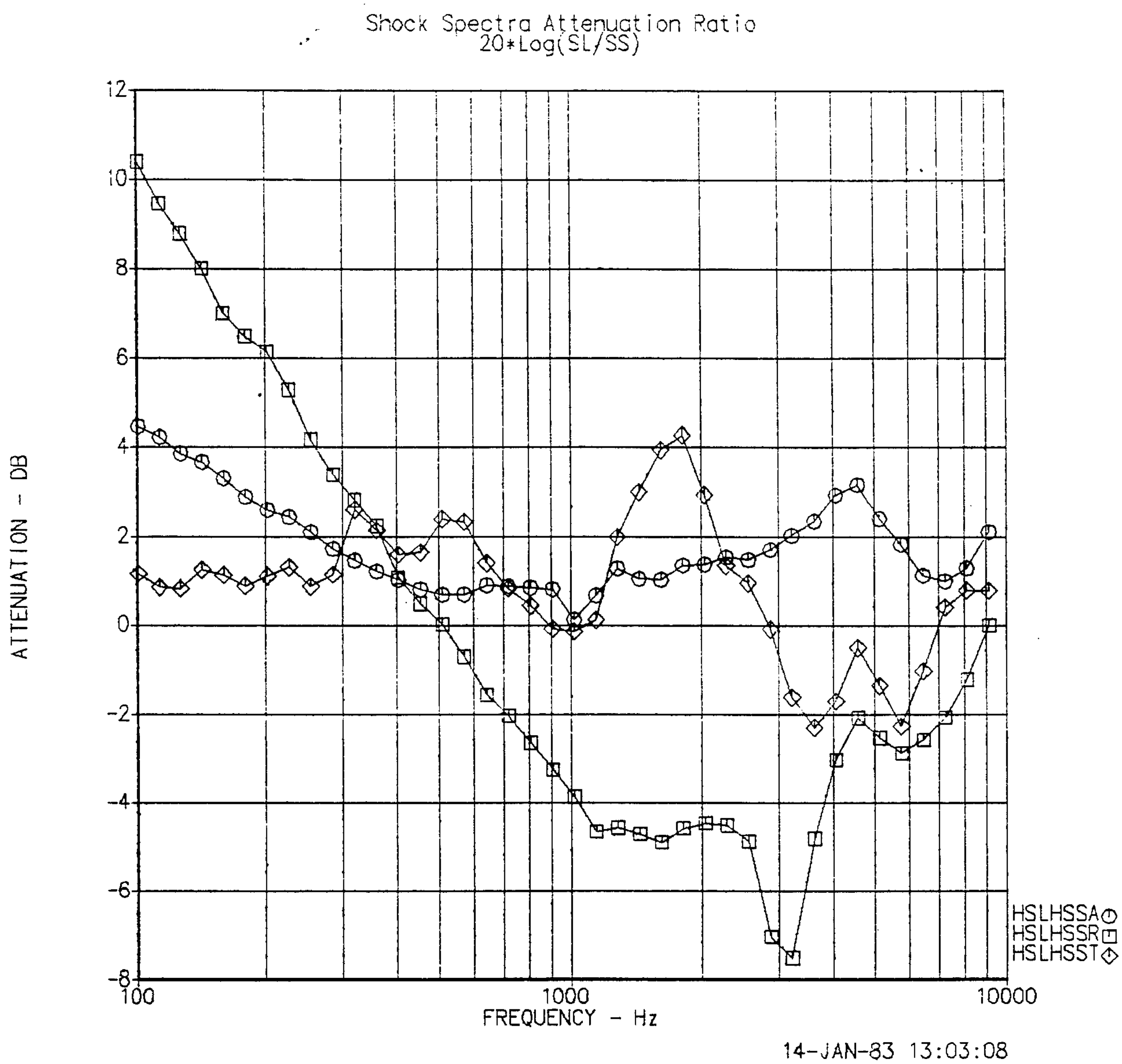

A1 = HSLHSS*.DB **Figure 6-3A**

Attenuation across the joint between the IUS ESS longeron and IUS 379 ring.

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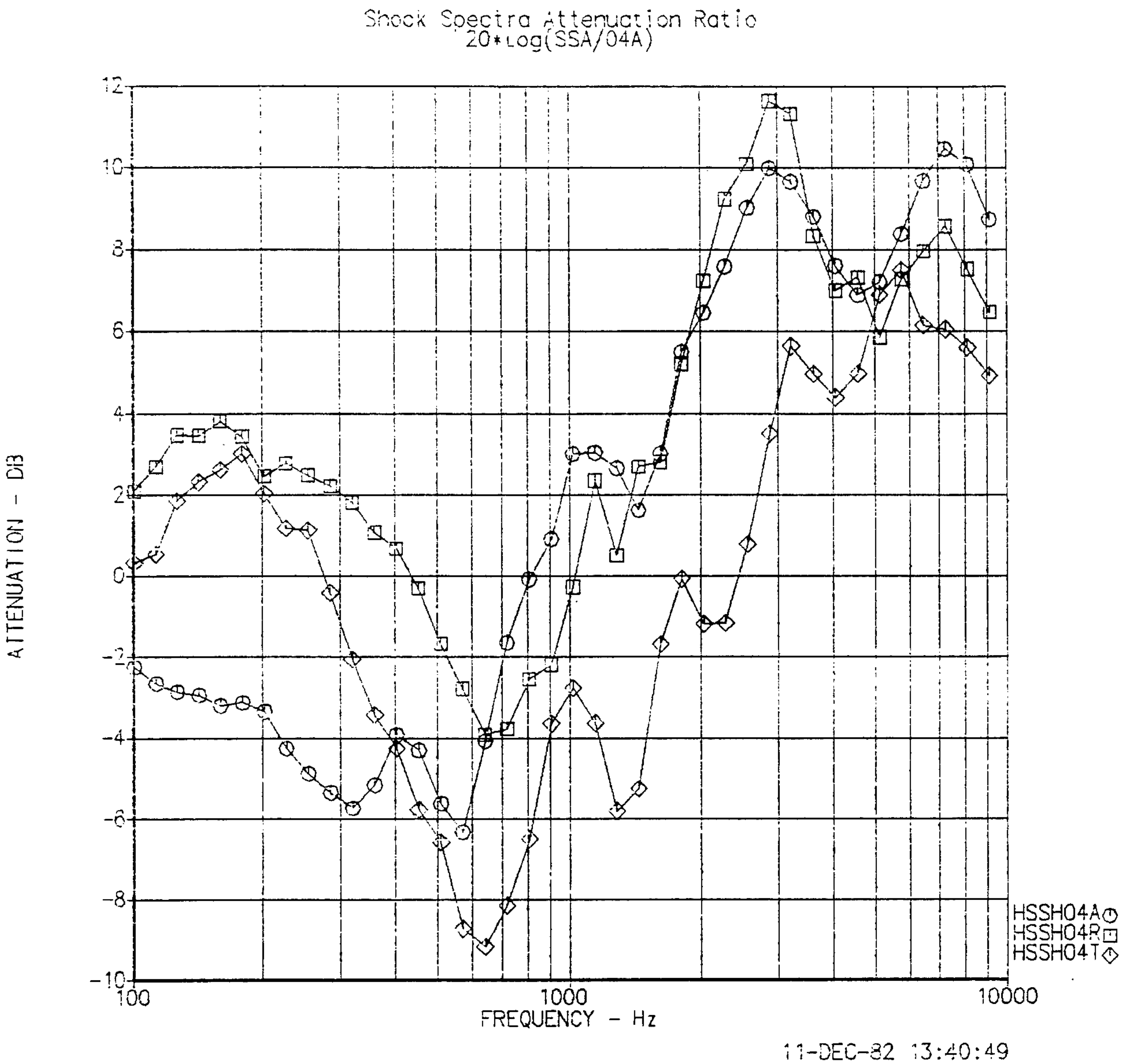

A2 = HSSH04*.DB **Figure 6-4**

Attenuation between the spacecraft attach point and the IUS REM located 26.6 inches from the attach point.

CALC	JB	11DEC82	REVISED	DATE	FIGURE 6-4	
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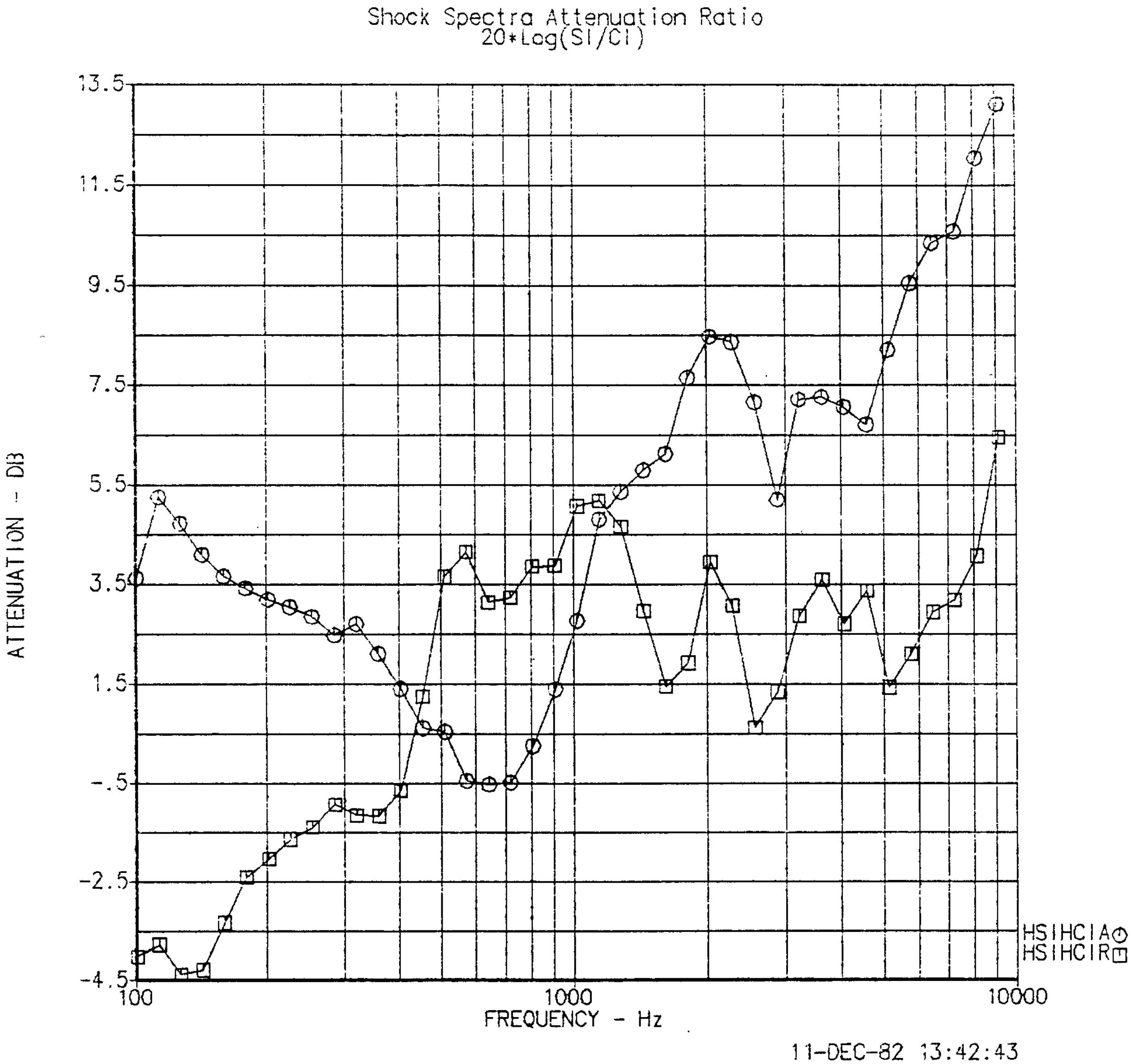

A3 = HSIHCI*.DB **Figure 6-5**
Attenuation between the IUS stage 1/2 separation nut and the computer isolator input.

CALC	GB	11DEC82	REVISED	DATE	FIGURE 6-5	
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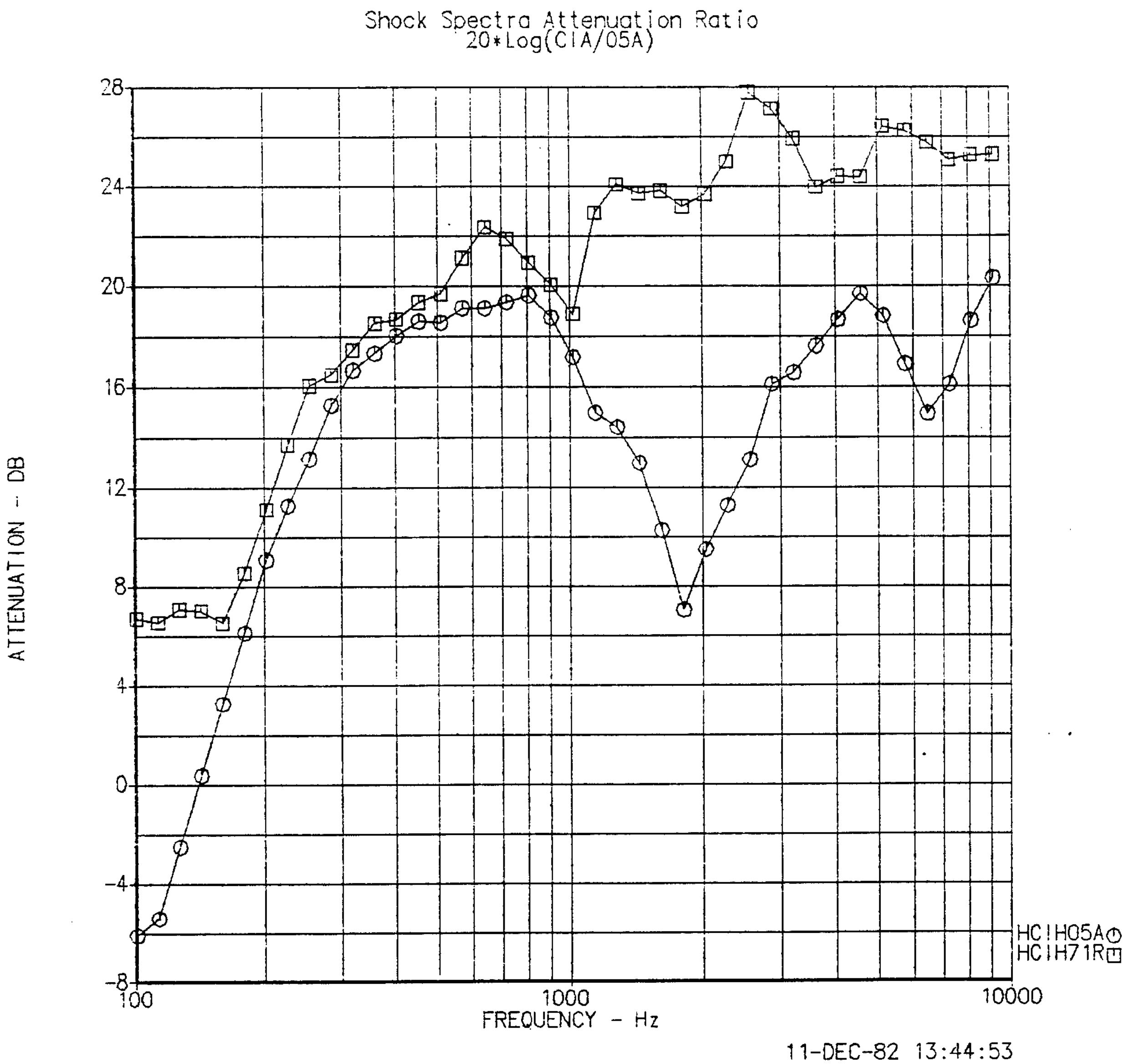

A4 = HCIH05A.DB and HCI H71R.DB **Figure 6-6**
Attenuation across the computer isolator.

CALC	JB	11DEC82	REVISED	DATE	FIGURE 6-6	
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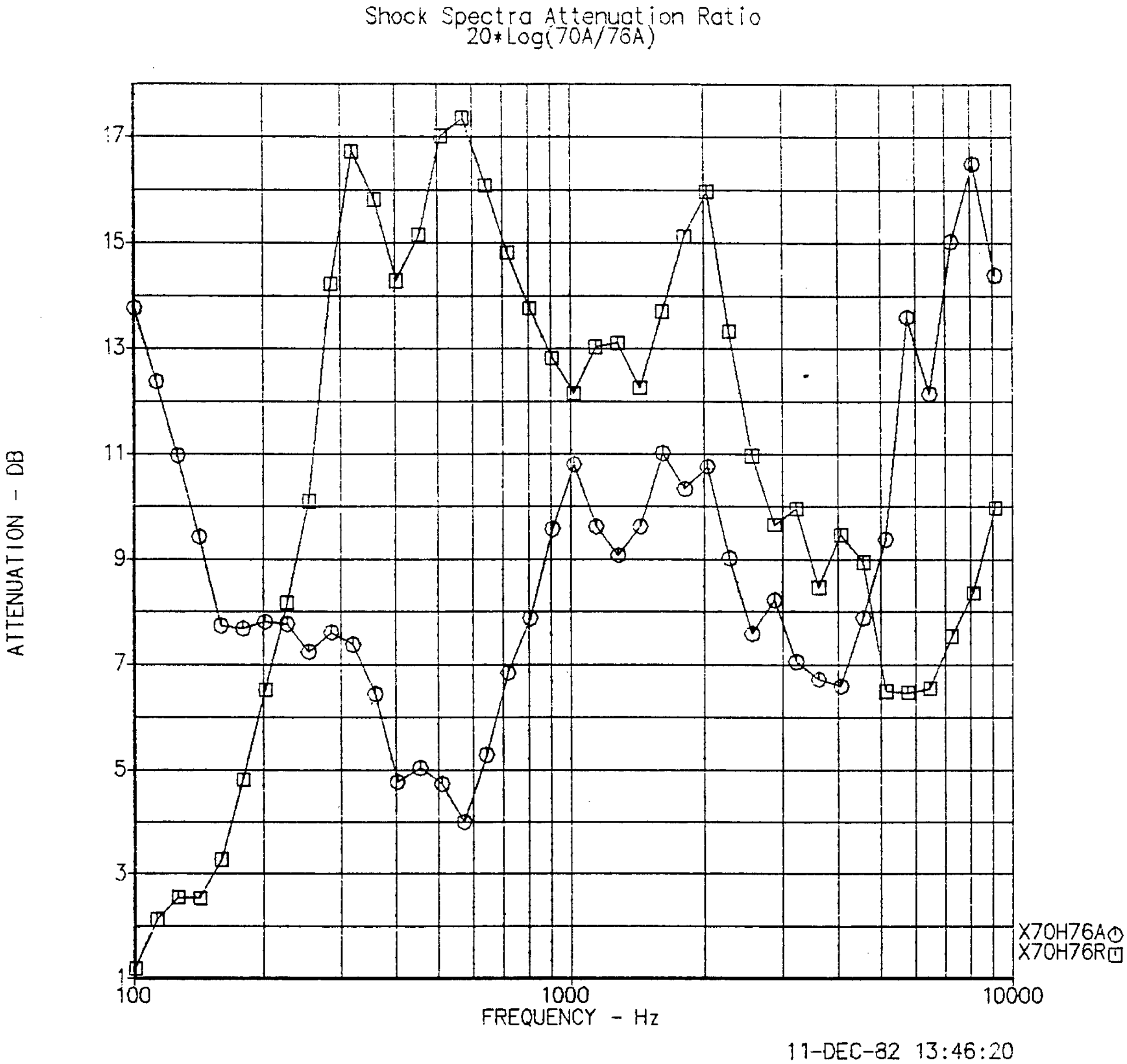

A5 = X70H76*.DB **Figure 6-7**

Attenuation between the IUS stage 1/2 separation nut and the power amplifier isolator input.

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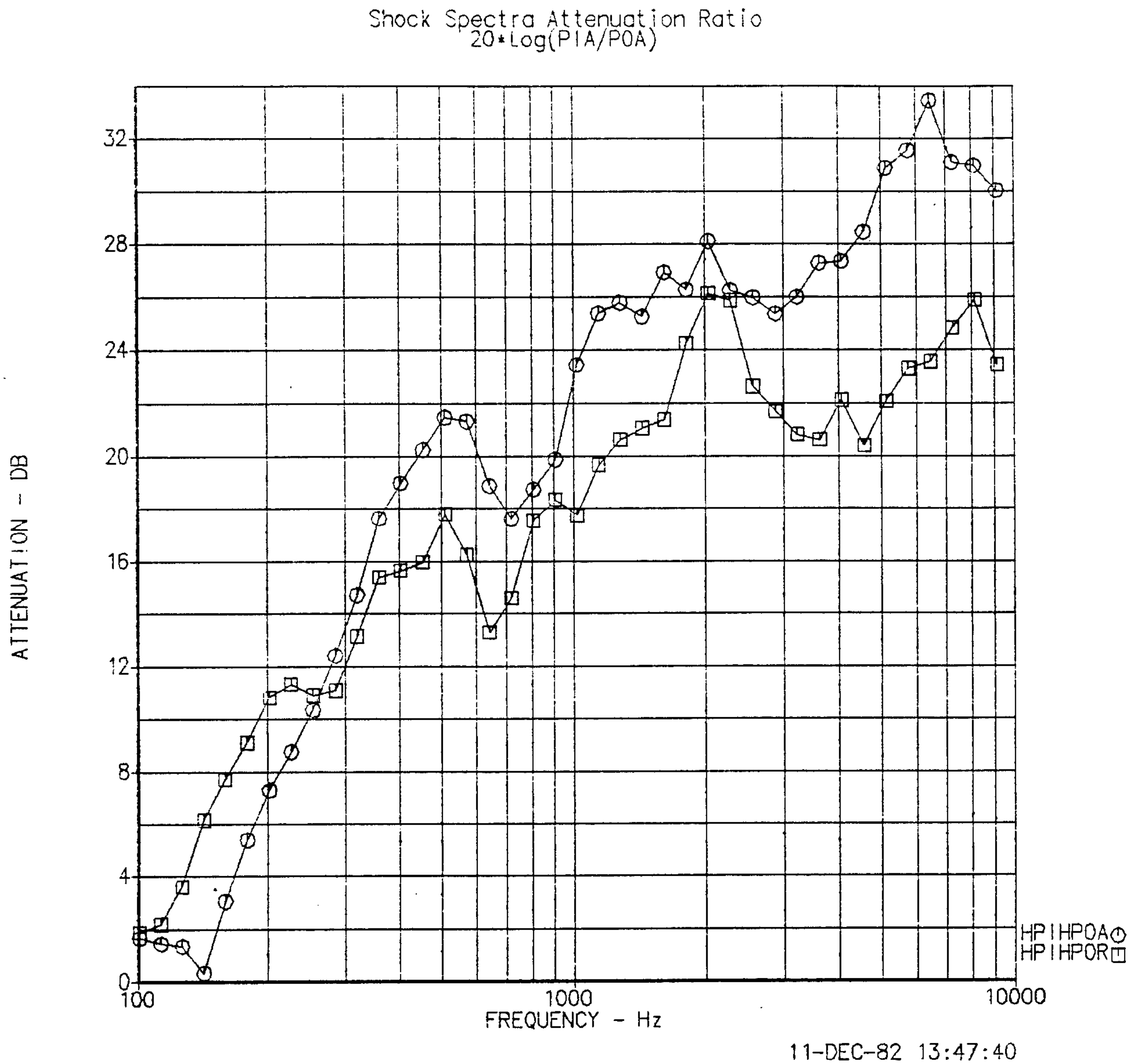

A6 = HPIHPO*.DB **Figure 6-8**

Attenuation across the power amplifier isolator.

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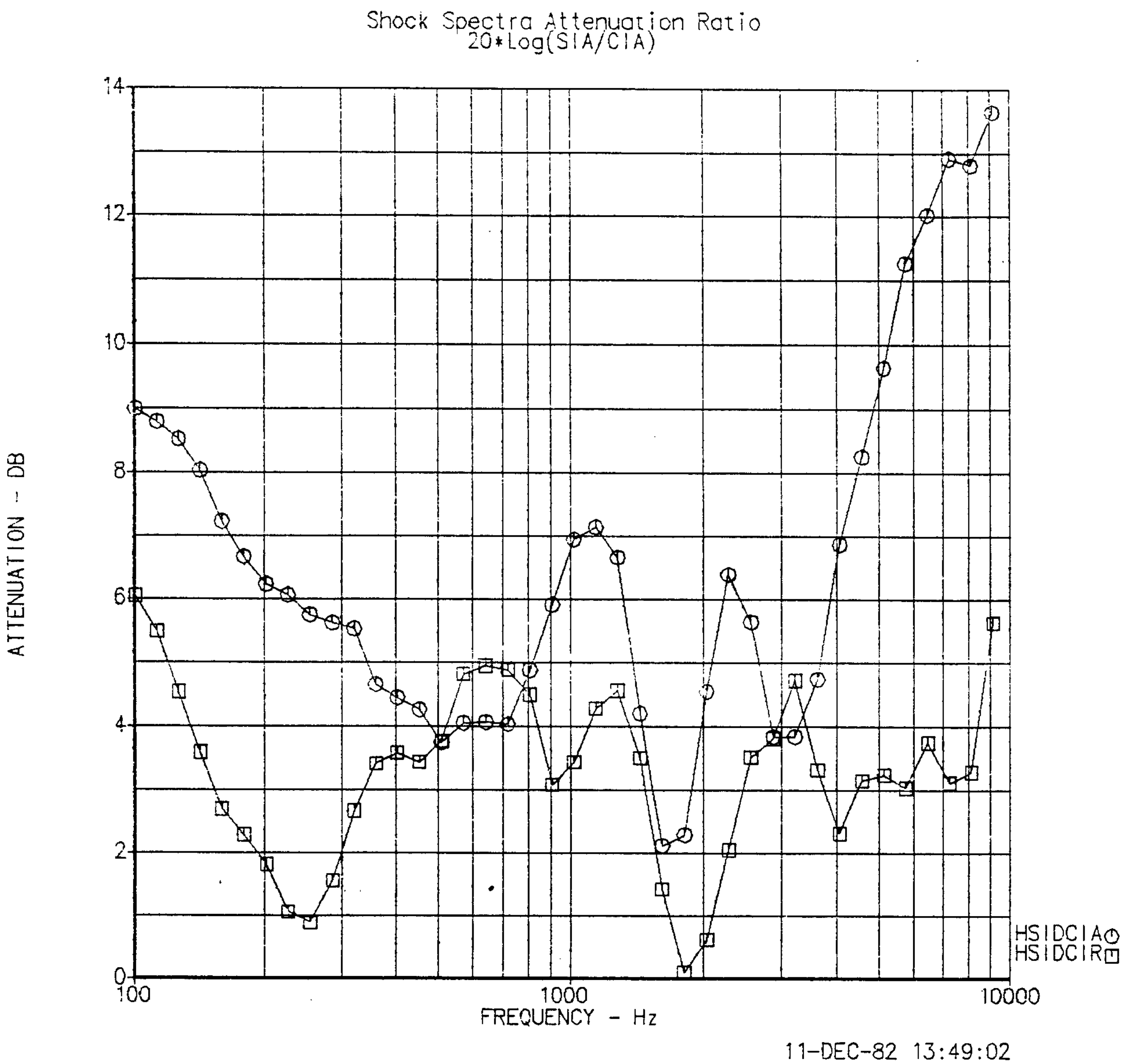

A7 = HSIDCI*.DB **Figure 6-9**

Attenuation between the IUS stage 1/2 separation nut and the DC-DC converter isolator input.

CALC	JB	11DEC82	REVISED	DATE	FIGURE 6-9	
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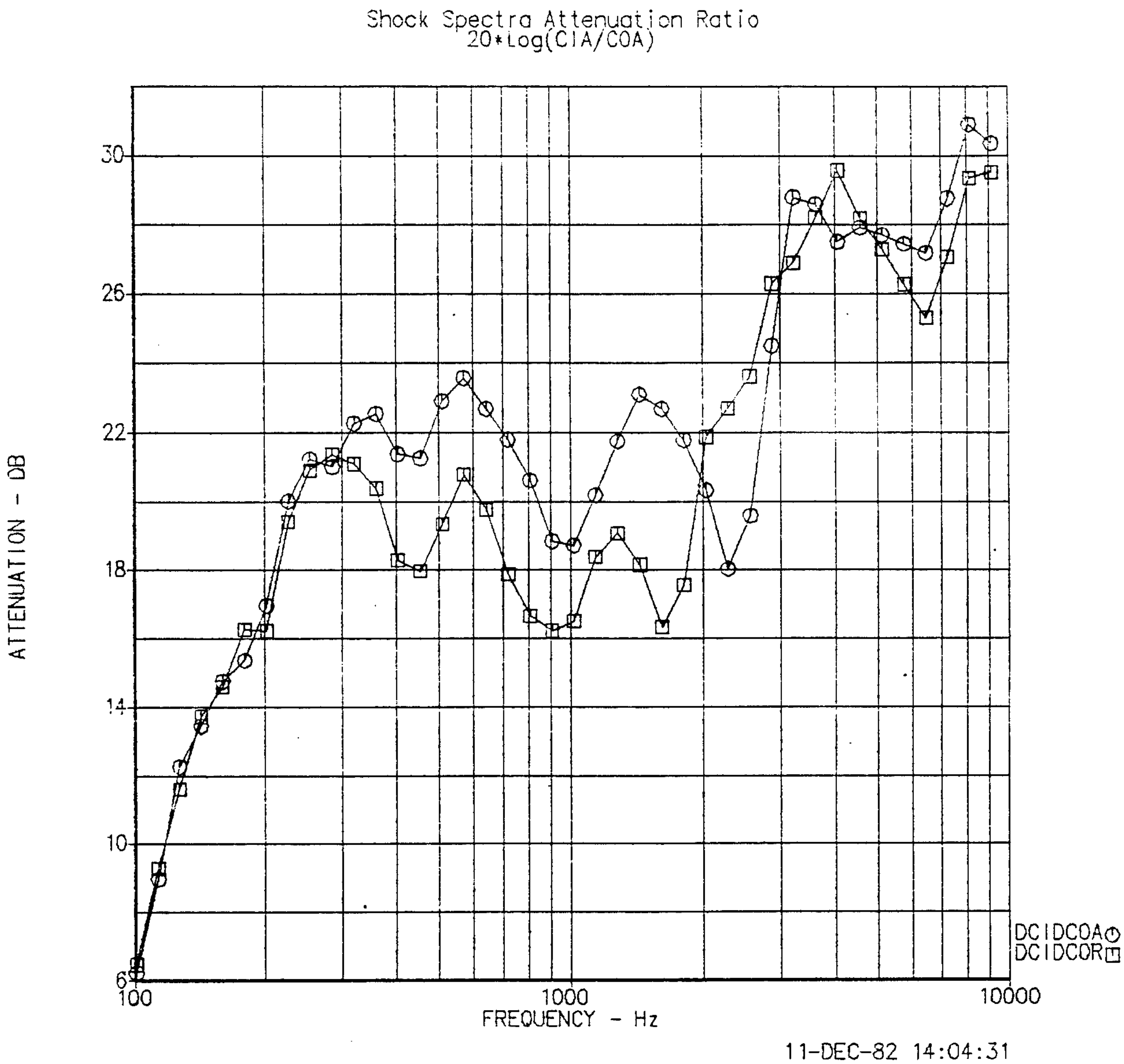

A8 = DCIDCO*.DB **Figure 6-10**
Attenuation across the DC-DC converter isolator.

CALC		11DEC82	REVISED	DATE	FIGURE 6-10	
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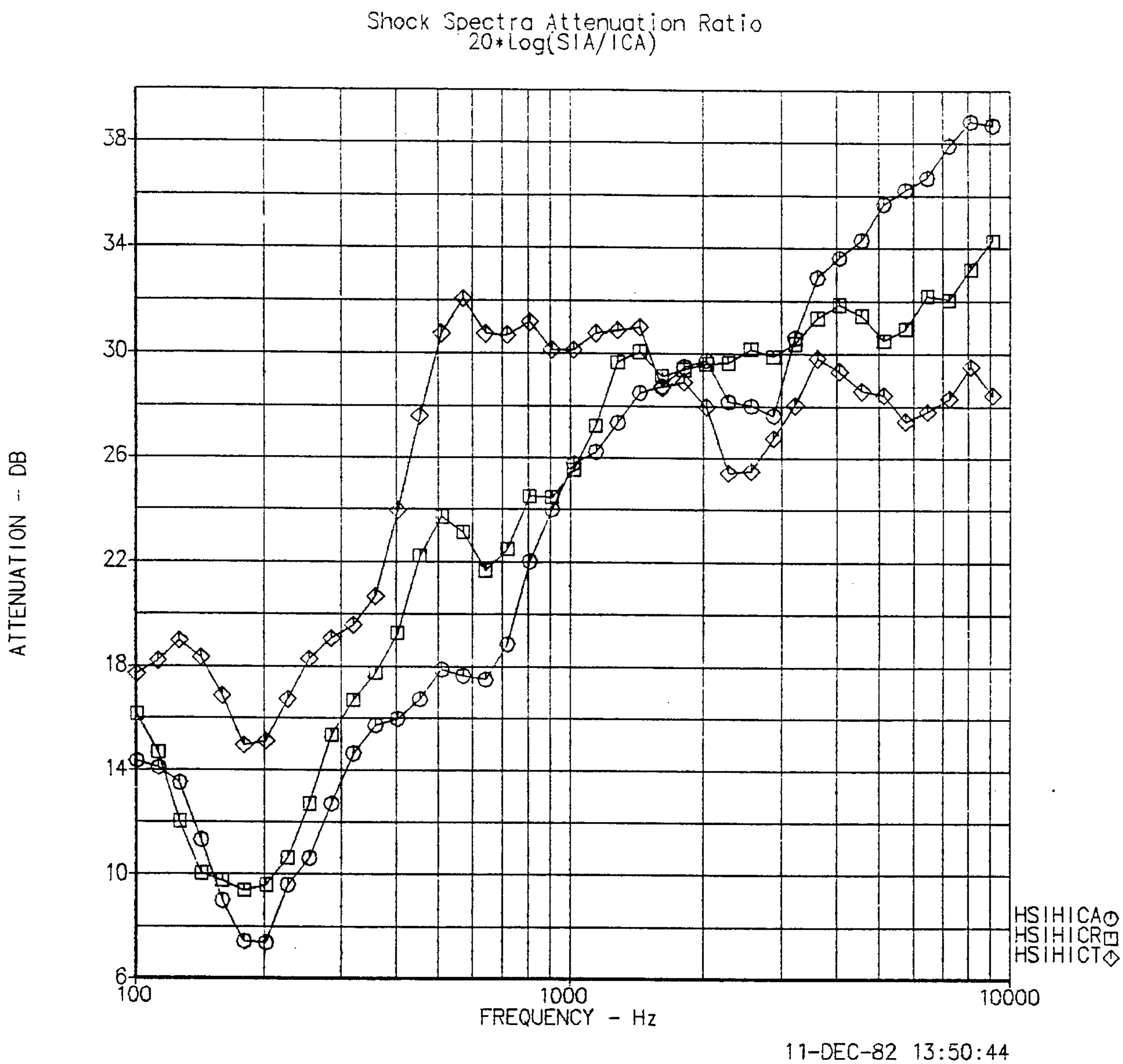

A9 = HSIHIC*.DB **Figure 6-11**

Attenuation between the IUS stage 1/2 separation nut and a location on the inner conic (40 inch shock path).

CALC	GB	11DEC82	REVISED	DATE	FIGURE 6-11	
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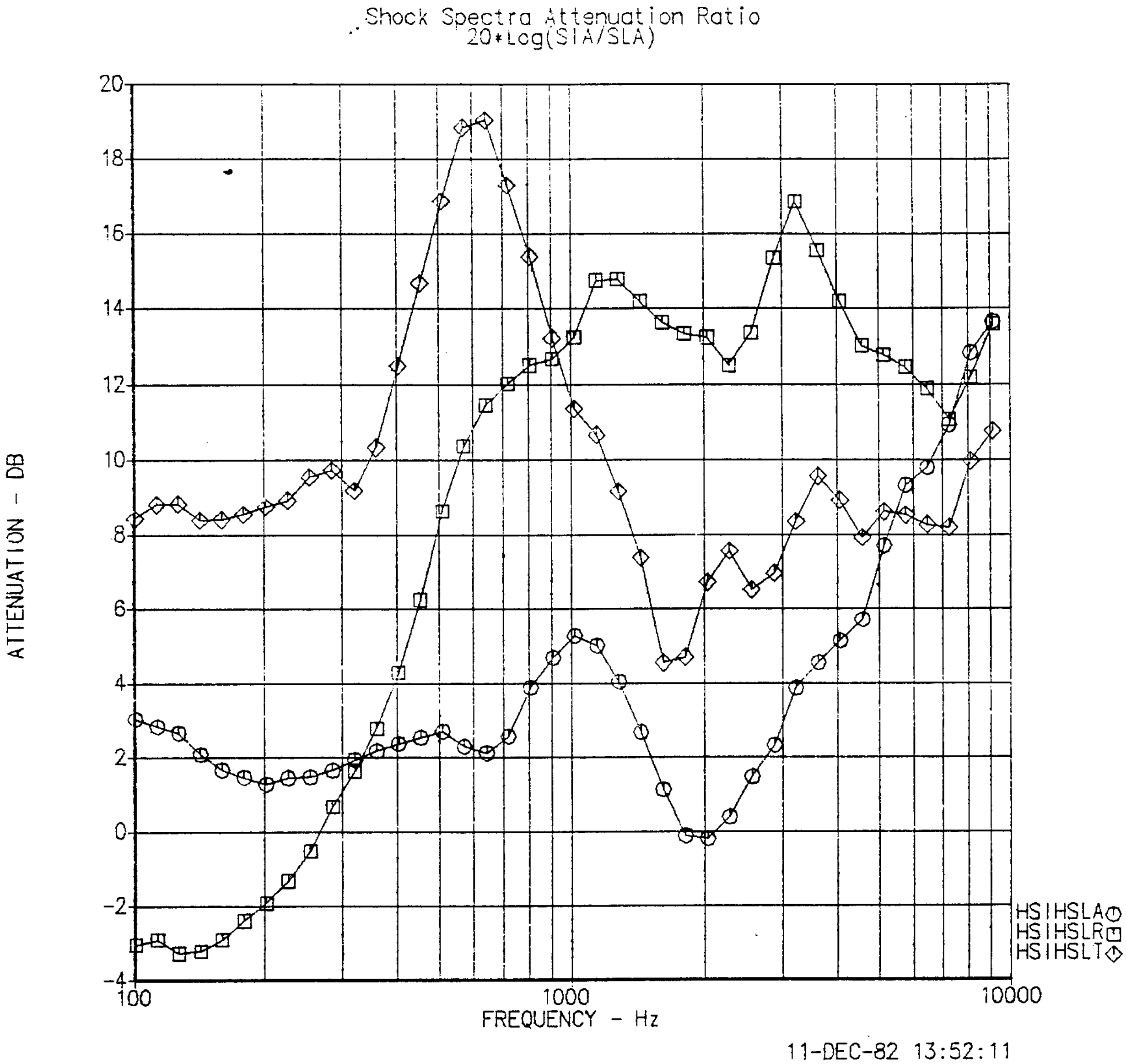

A10 = HSIHSL*.DB **Figure 6-12**
Attenuation between the IUS stage 1/2 separation nut and the top of the ESS longeron (16 inch shock path).

CALC	JB	11DEC82	REVISED	DATE	FIGURE 6-12	
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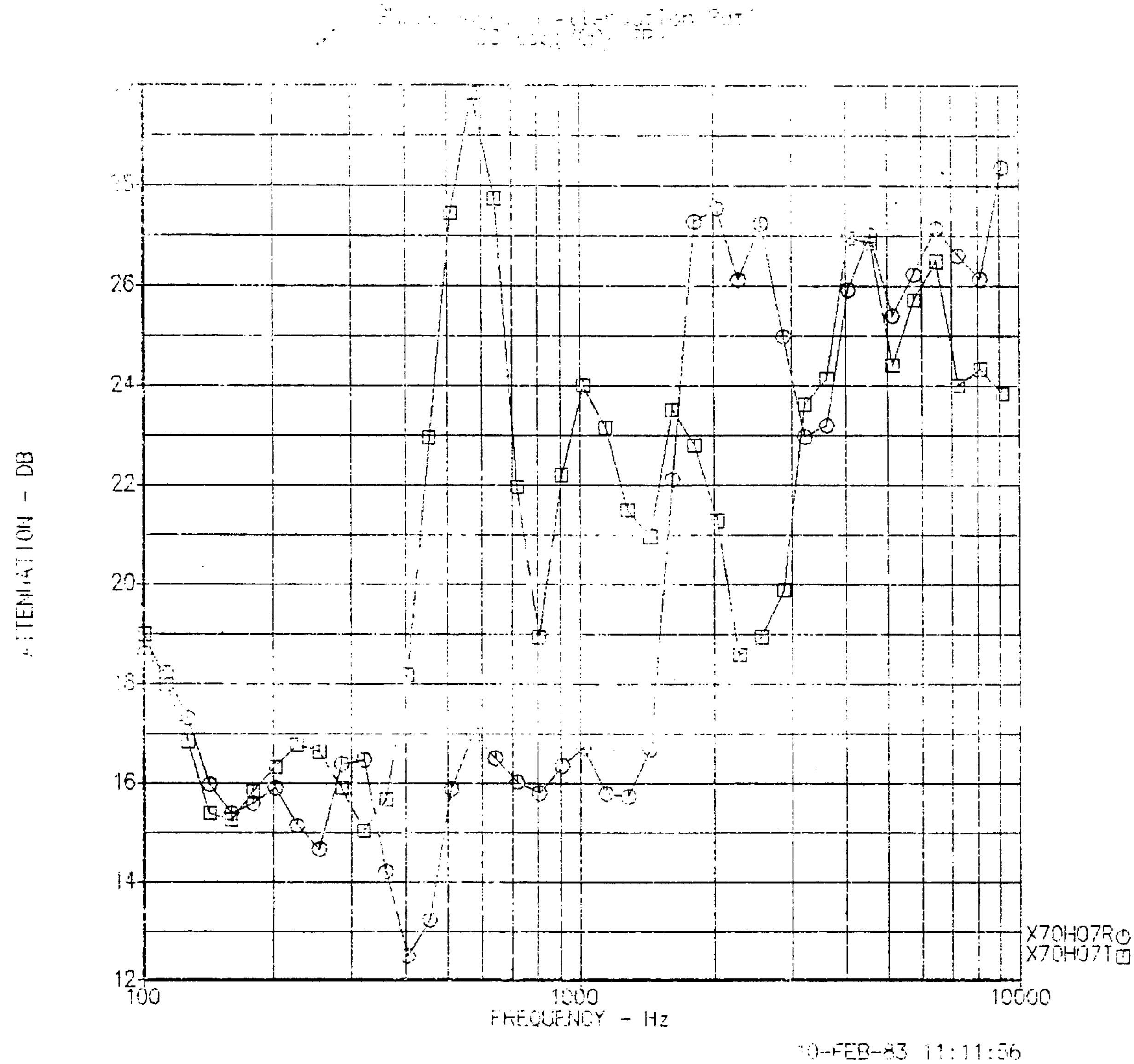

A11 = X70H07*.DB **Figure 6 -12A**

Attenuation between the IUS stage 1/2 separation nut and the ESS battery support (21 inch shock path).

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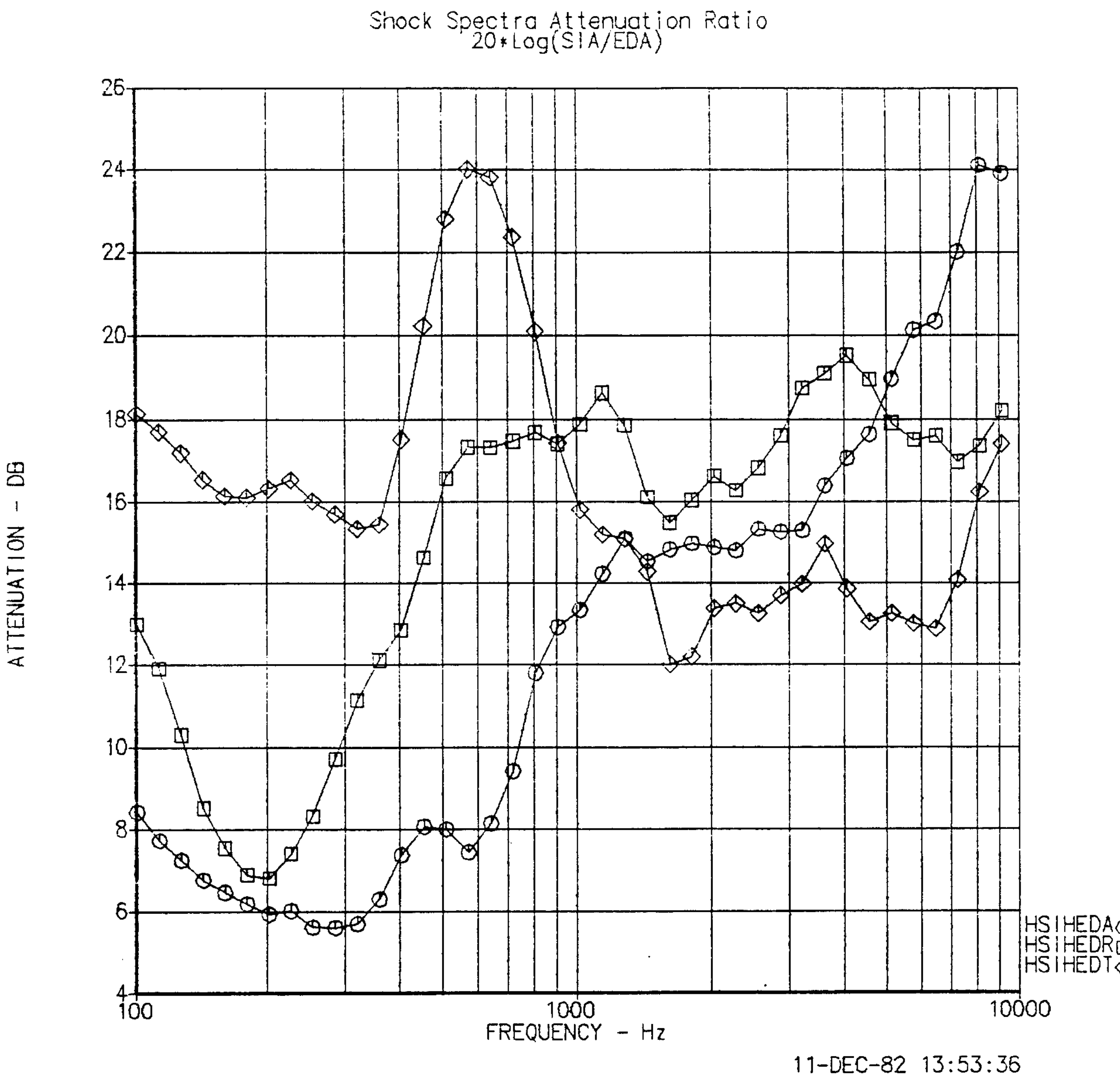

A12 = HSIHED*.DB Figure 6-13
Attenuation between the IUS stage 1/2 separation nut and the ESS deck (16 inch shock path).

CALC	JJB	11DEC82	REVISED	DATE	FIGURE 6-13	
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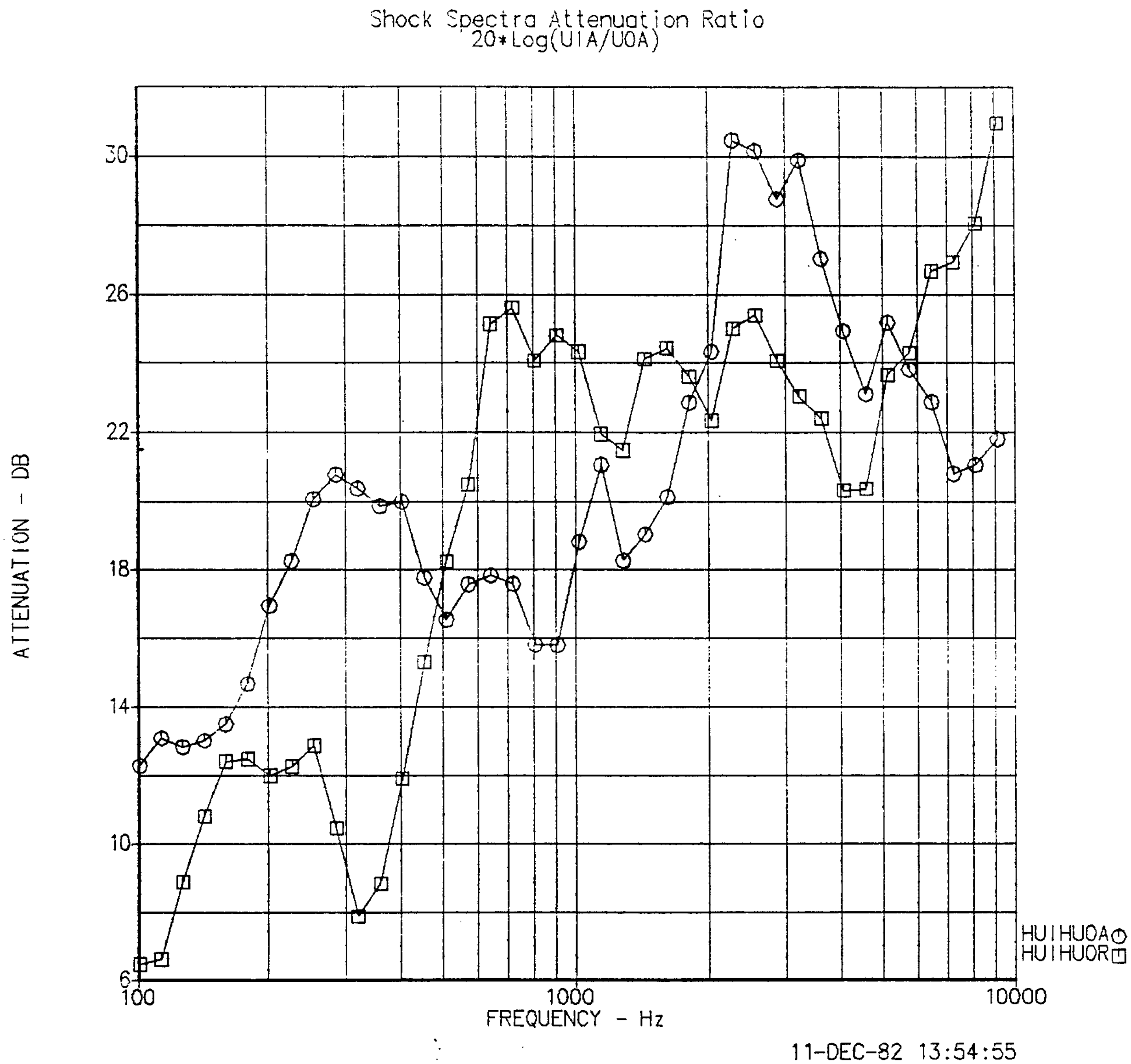

A13 = HUIHUO*.DB
Attenuation across the PDU isolator.

Figure 6-14

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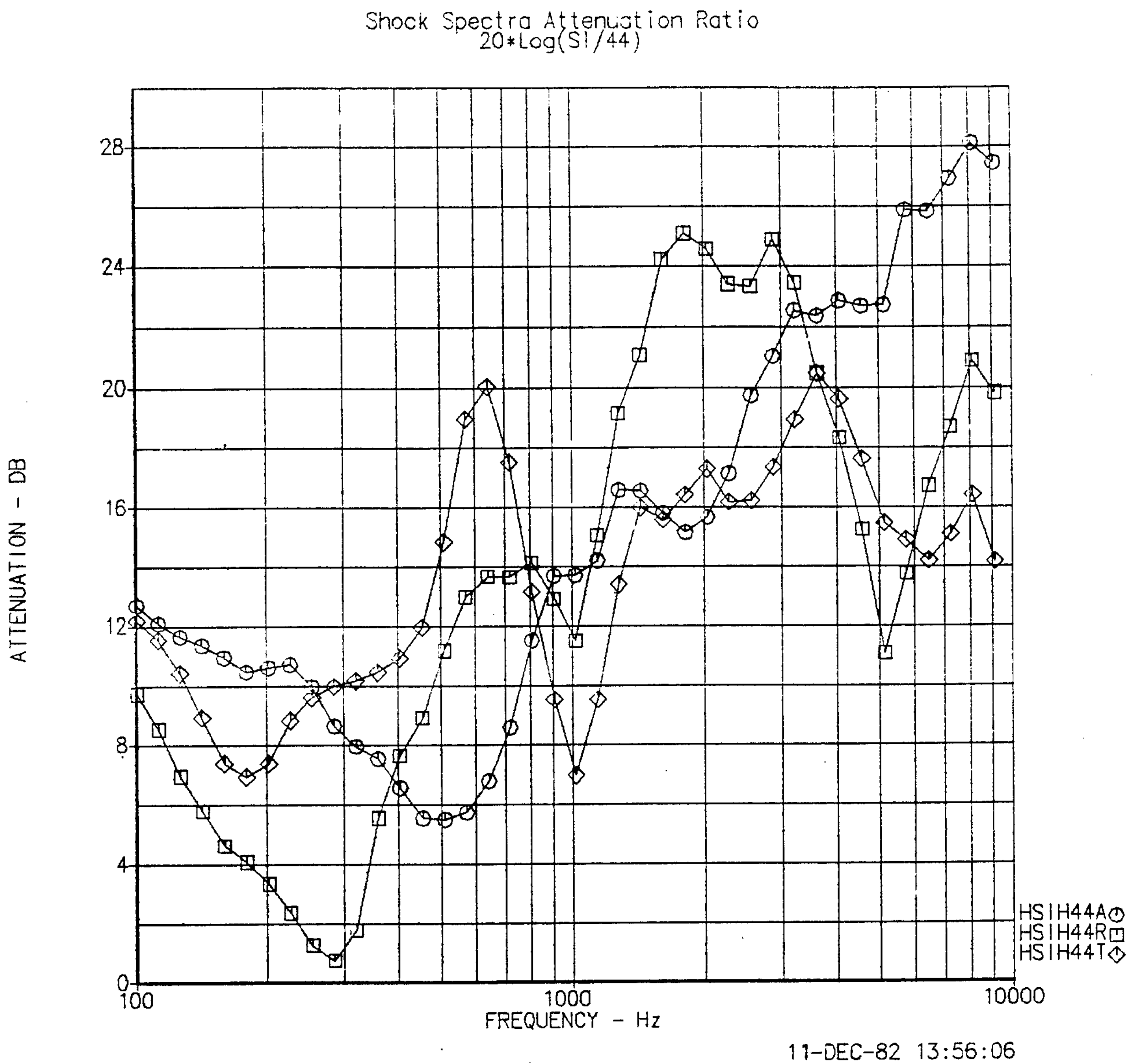

A14 = HSIH44*.DB **Figure 6-15**

Attenuation between the IUS stage 1/2 separation nut and the RF switch support (40 inch shock path).

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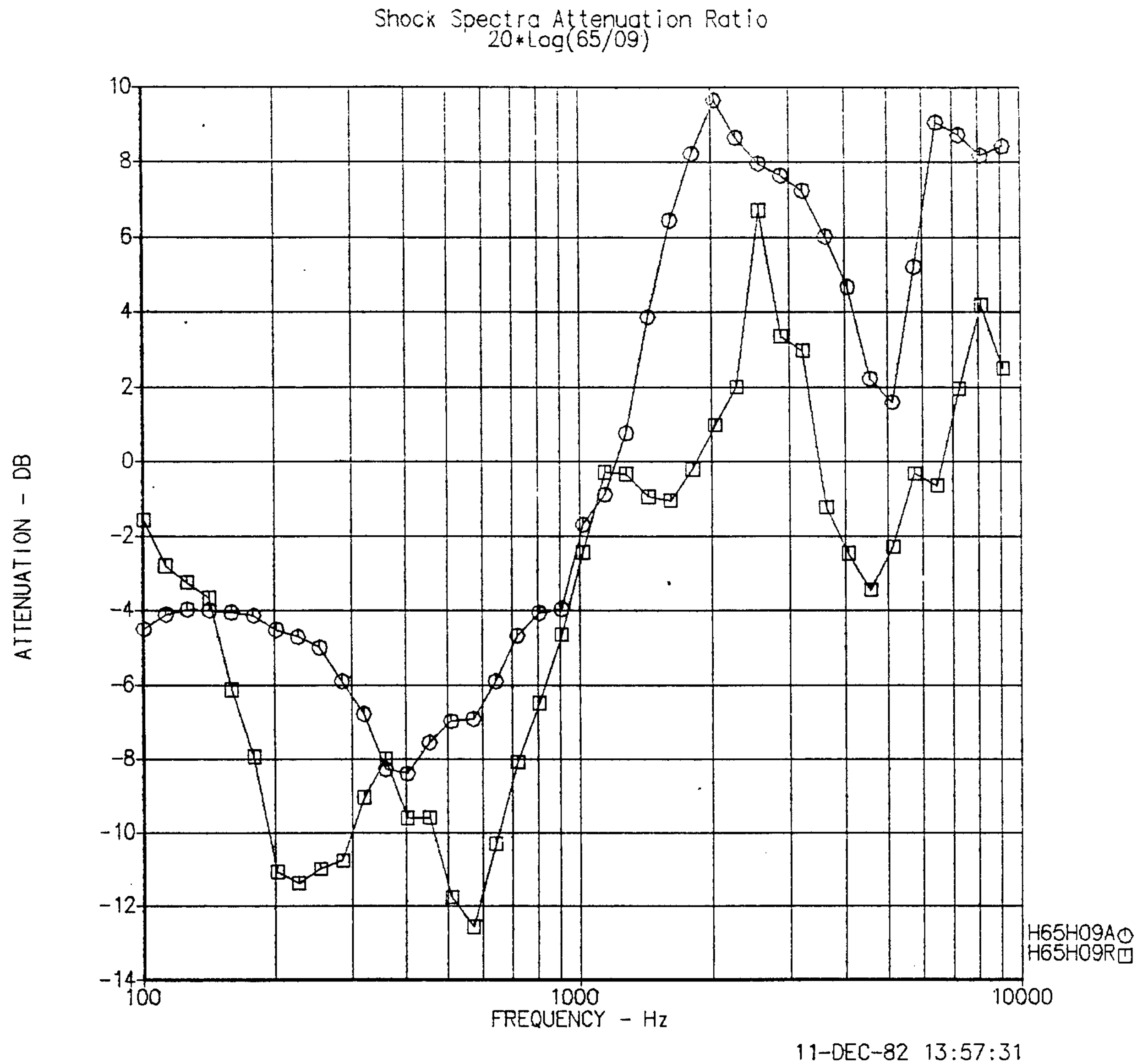

A15 = H65H09*.DB **Figure 6-16**
Attenuation between spacecraft attach point and SRM 2 safe and arm isolator.input (30 inch shock path).

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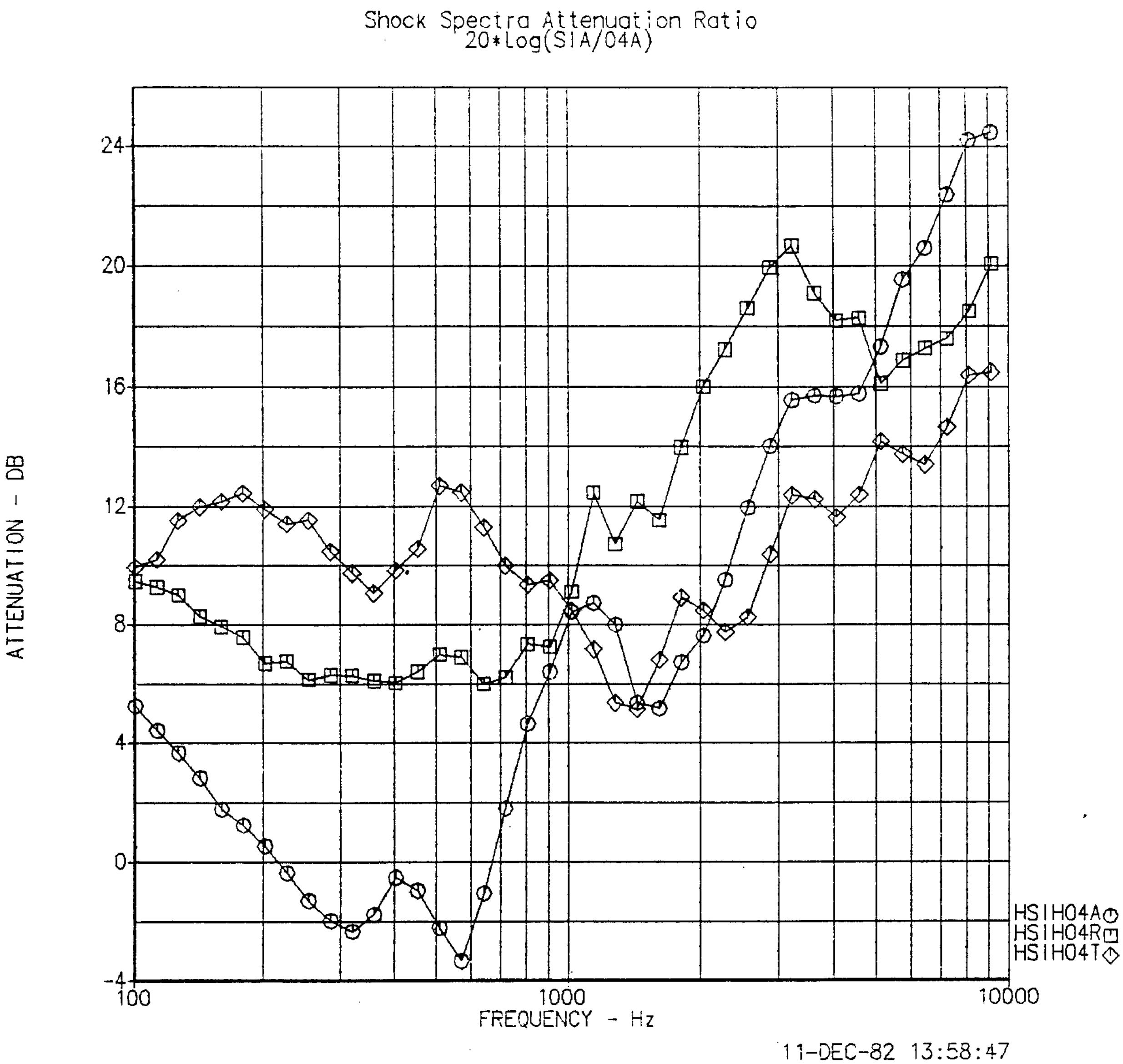

A17 = HSIH04*.DB **Figure 6-17**
Attenuation between the IUS stage 1/2 separation nut and REM location (30 inch shock path).

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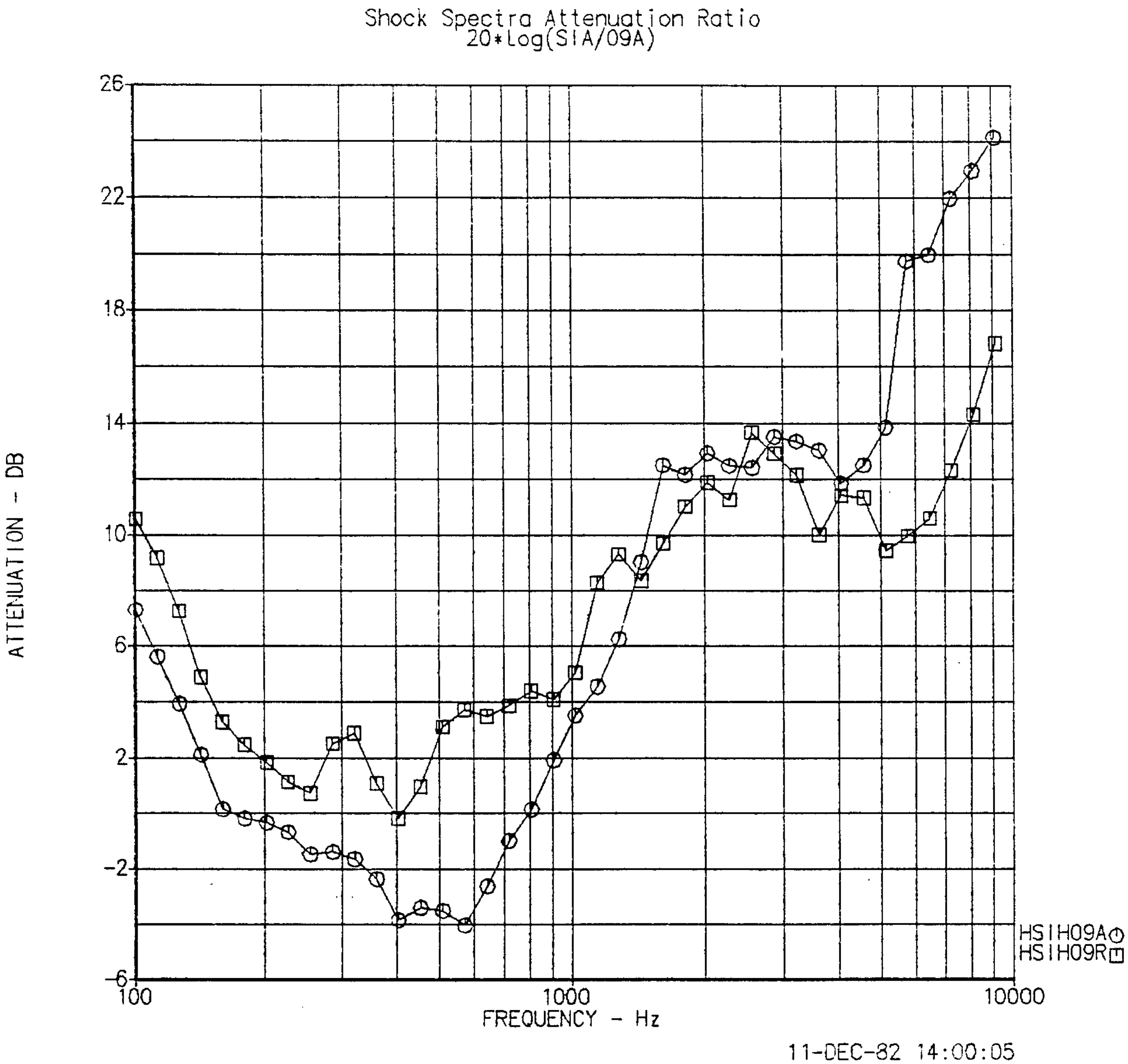

A18 = HSIH09*.DB **Figure 6-18**

Attenuation between the IUS stage 1/2 separation nut and SRM 2 safe and arm (30 inch shock path).

CALC	GB	11DEC82	REVISED	DATE	FIGURE 6-18	
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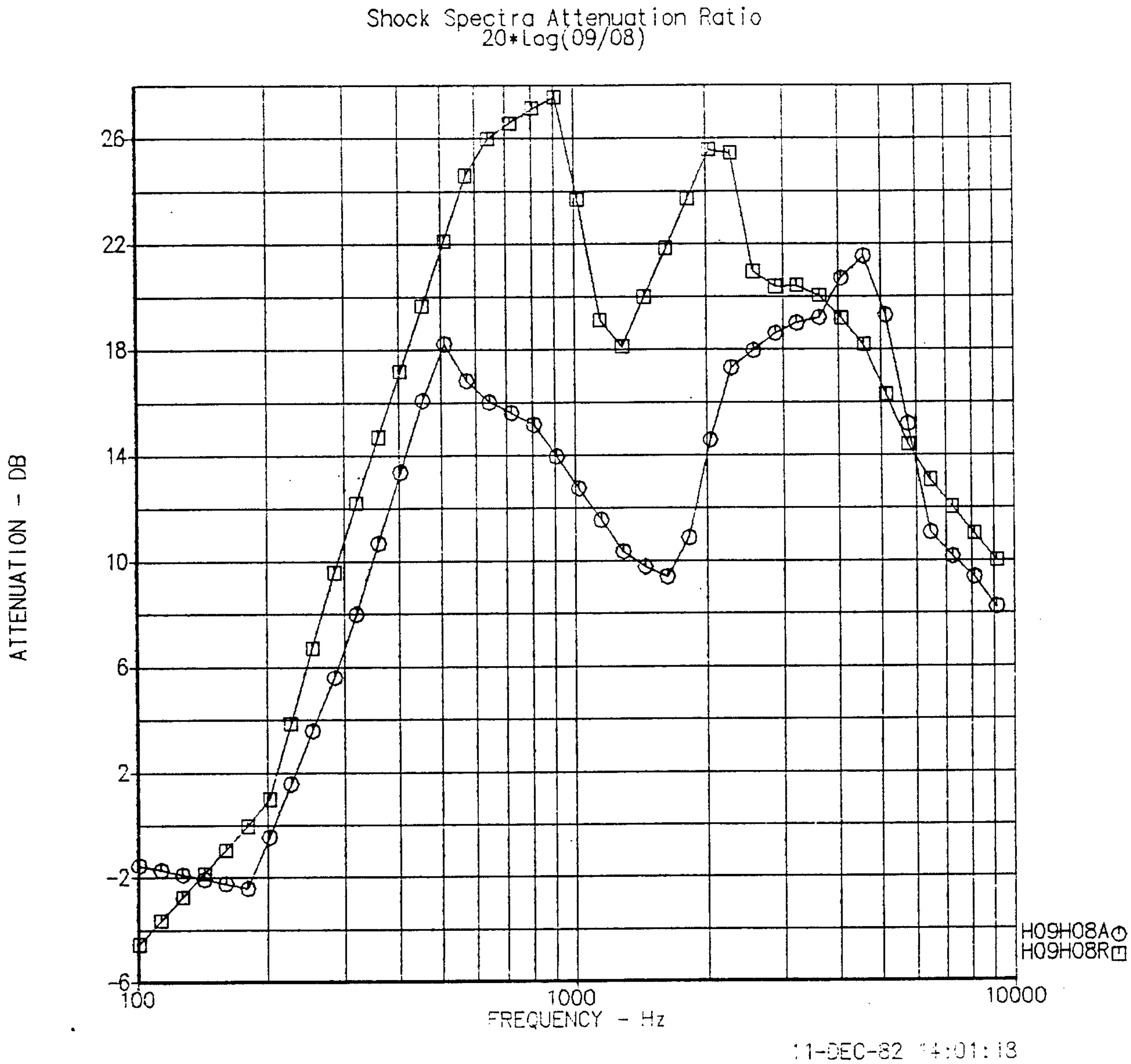

A19 = H09H08*.DB **Figure 6-19**
Attenuation across the safe and arm isolator.

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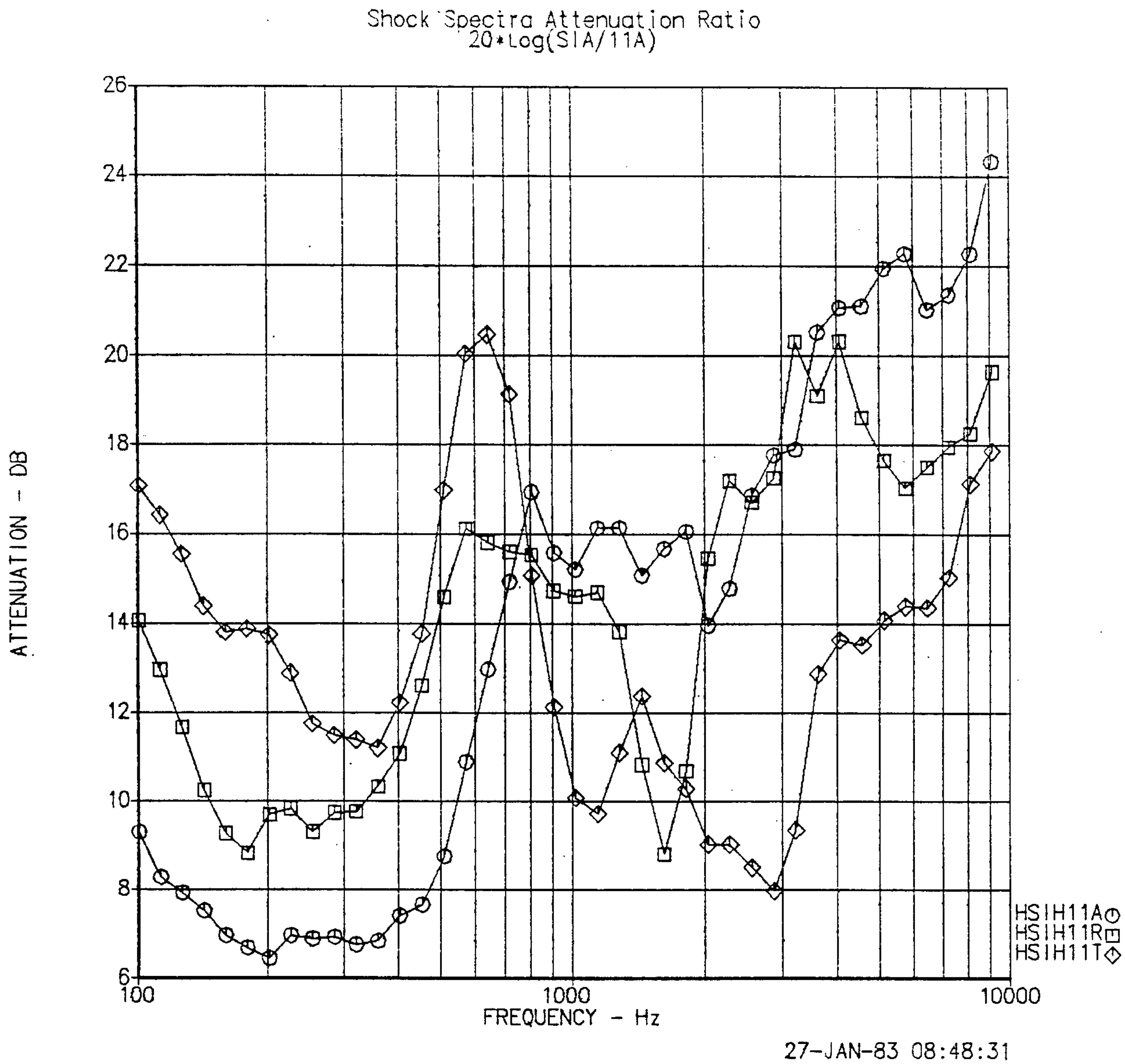

A20 = HSIH11*.DB **Figure 6-20**

Attenuation between the IUS stage 1/2 separation nut and the SCU (8 inch shock path).

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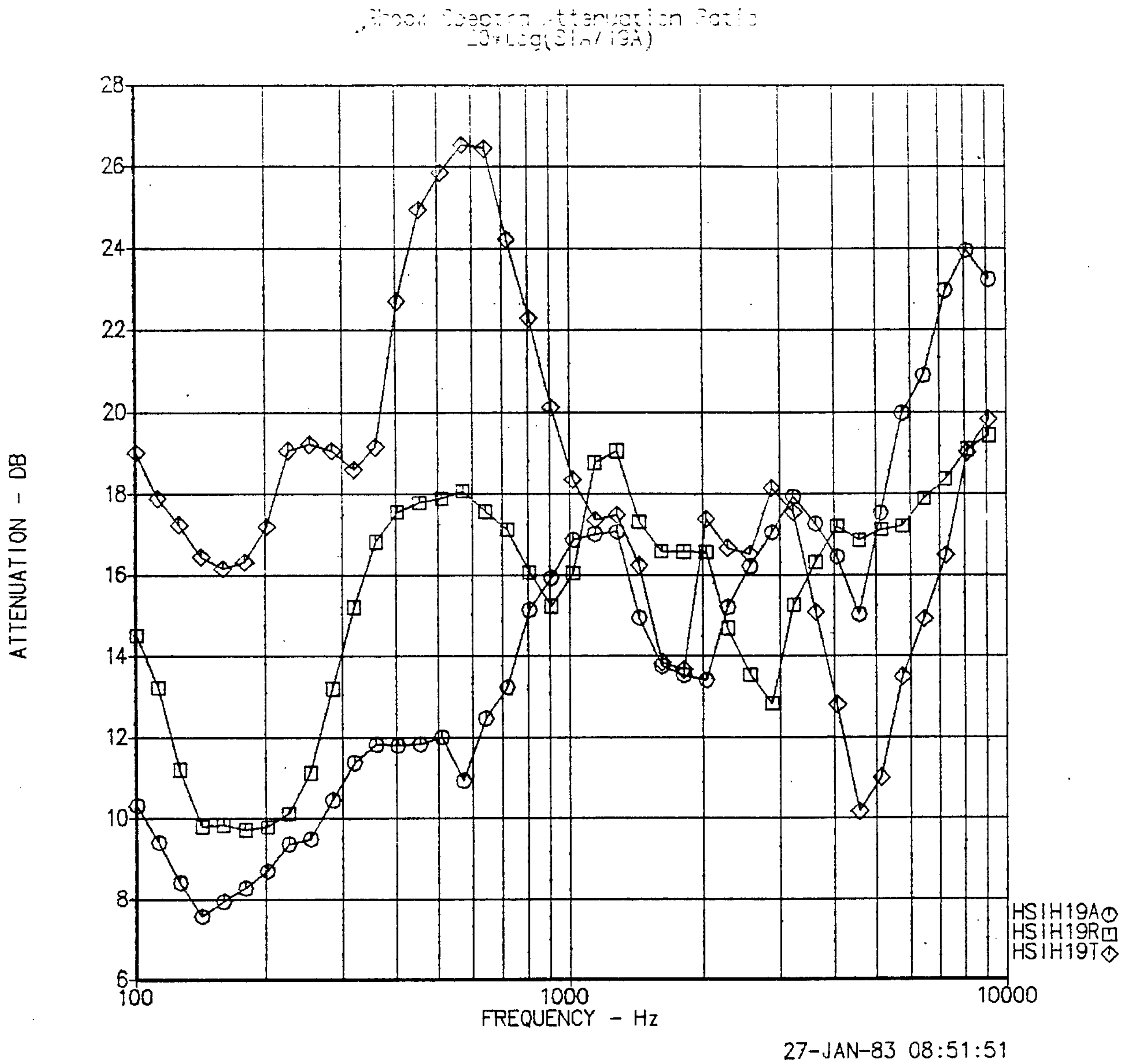

A21 = HSIH19*.DB **Figure 6-21**
Attenuation between the IUS stage 1/2 separation nut and the Star Scanner (8 inch shock path).

CALC	CB	27JAN83	REVISED	DATE	FIGURE 6-21
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REFERENCES

1. S290-70001A, Prime Item Development Specification for DOD Two-Stage Vehicle, Inerial Upper Stage, CI290007A. 12 June 1981.

2. TIS No. 11-2-002-1, IUS Separation Test - Pyrotechnic Shock, Boeing Aerospace Co. Final Test Report (T + 45 Day CDRL 077A2), dated 20 February 1978.

3. Figure 11 of Boeing letter 2-3944-0000-662, to Dept. of Air Force, subject, Submittal of Shock and Vibration Environments for IUS Prime Item And Critical Item Specs, 15 March 1978.

4. D290-10080-1, Subsystem Design Analysis Report, Environmental Vibration, Revision D, 27 February 1978.

5. Final Report Special Study FSD-81-003, "IUS Pyrotechnic Shock Reduction, Stage 1/2 Separation", 10 July 1981.

6. Boeing Memo 2-3612-IUS-590; to S. M. Church from C.J. Beck; subject, Compatibility Analysis, IUS Components with DSCS Induced Shock; dated 29 April 1982.

7. Boeing Memo 2-3612-IUS-614; to S. M. Church from C.J. Beck; subject, Compatibility Analysis, IUS Components with DSP Induced Shock; dated 28 May 1982.

8. Boeing Memo 2-3612-IUS-625; to S. M. Church from C.J. Beck; subject, Compatibility Analysis, IUS Components with TDRS Induced Shock; Revision A dated 6 October 1982.

9. Boeing Test Report 22B1-001R, Report on Test of Signal Conditioner Unit S/N 0004, dated 4 March 1982.

Attachment to

2-3612-IUS-614

APPENDIX D

Evaluation of
IUS Equipment Compatibility
with the DSP 12, 13
Separation Shock Environment

Date 28 May 82
Revision A 4 March 1983
Revised pages 1,5,25,26,27 89,90,92,93,94,95,96 A

Revision B
6 January 1983 A

Revised pages 1,2,5,6,76,77,89,90,92 A

Prepared by
C.J. Beck

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1.0 INTRODUCTION

Purpose

The purpose of this evaluation is to determine the compatibility of IUS equipment with the pyrotechnic shock environment induced by firing the devices used to separate DSP 12, 13 from IUS Stage 2.

Background

IUS Stage 2 equipment was designed and qualified for pyroshock environments based on measured shock data from the IUS DTV Stage 1/2 separation test conducted in 1978, Reference 1. The spacecraft induced shock allowable was established from the same IUS DTV shock data. The IUS equipment design environment is shown on Figure 1.0. The IUS equipment environment is an envelope of all shock spectra measured at equipment attach points on the DTV. Reference 2 discusses the derivation of the IUS equipment environment. The spacecraft induced shock allowable on the IUS 379 ring as shown on Figure 1.0 is the envelope of shock spectra measured 3.5 inches from the IUS DTV separation nut. The induced shock environment envelope derived from data measured on the IUS QTV spacecraft interface ring is also shown on Figure 1.0. The IUS QTV environment was measured on the IUS QTV 379 ring, Reference 3. There was no load on the IUS QTV ring during the separation shock test. No separation tests have been conducted with an IUS/Spacecraft configuration to measure the response of IUS equipment to spacecraft induced shock.

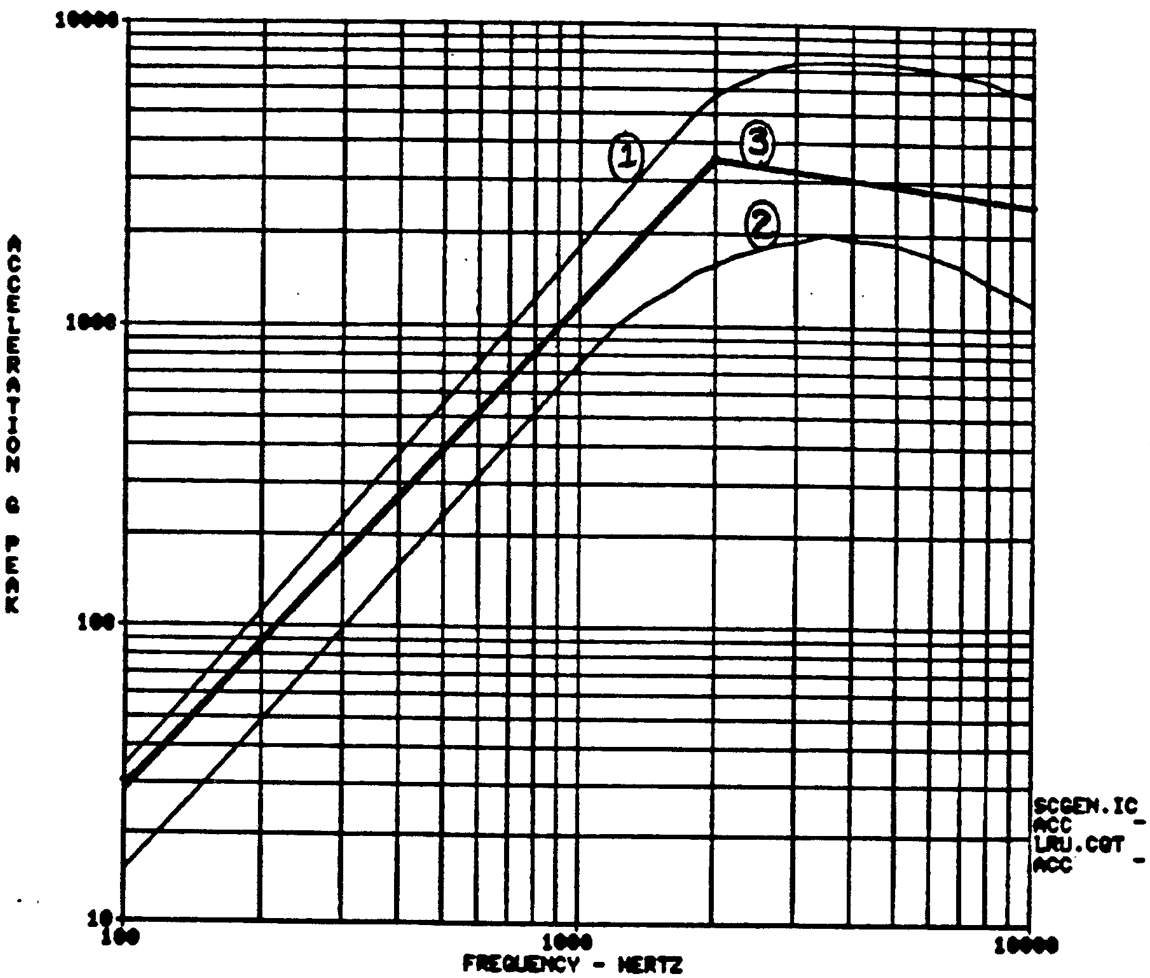
Scope

This document contains an evaluation of IUS equipment compatibility with DSP 12,13 induced separation shock. Section 2 presents a list of IUS equipment annotated to indicate equipment which must function after the spacecraft separation shock event. Section 3 discusses the analysis method used to predict the IUS equipment response to DSP induced shock and contains shock spectra comparing the predicted DSP induced shock with the IUS equipment capability. Section 4 presents conclusions. Section 5 describes the derivation of the DSP shock. R

2.0 IUS EQUIPMENT LIST/FUNCTION

Figure 2.0 lists IUS equipment which was evaluated for compatibility with DSP 12,13 induced separation shock. Figure 2.0 also indicates the IUS equipment which is required to function after the DSP separation shock event. DSP 12,13/IUS will be launched from a T34D launch vehicle. Shock compatibility analyses were performed for IUS equipment (T34D configuration) which is required to function after the DSP separation shock event. The analyses are discussed in Section 3.

Reference 1. TIS No. 11-2-002-1, IUS Separation Test - Pyrotechnic Shock, Boeing Aerospace Co. Final Test Report (T+45 Day CDRL 077A2), dated 20 February 1978.
Reference 2. D290-10080-1, Subsystem Design Analysis Report. Environmental Vibration, Revision D, 27 February 1978.
Reference 3. Final Report Special Study FSD-81-003, "IUS Pyrotechnic Shock Reduction, Stage I/II Separation", 10 July 1981.



COMPARISON

1. Spacecraft Induced Shock Allowable
2. IUS Equipment Design Requirement
3. IUS Induced Shock Envelope at IUS 374 Ring, Measured on QTV

FIGURE 1.0

FIGURE 2.0

IUS/DSP EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO DSP SEP	REQD AFTER DSP SEP	
SRM-1	290-21000	X	X	X		
Safe & Arm	290-21005/C1290014A	X	X	X		
SRM-2	290-21001/C1290012A	X	X	X		
Safe & Arm	290-21005/C1290014A	X	X	X		
REM	290-21002/C1290020A	X	X		X	X
Manifold	290-21024	X	X		X	X
Tank Module Assy	290-21007	X	X		X	X
Resistor Board Assy	290-21066/C1290A30A	X	X		X	X
Star Scanner	290-22127/C1290039A	--	X	Not Applicable		
Inertial Meas. Unit	290-22118/C1290024A	X	X		X	X
TVC Actuator	290-22116/C1290015A	X	X	X		
TVC Controller	290-22116/C1290015A	X	X	X		
TVC Potentiometer	290-22116/C1290015A	X	X	X		
Computer, Central Avion.	290-22119/C1290025A	X	X		X	X
Signal Cond. Unit (SCU)	290-26016/C1290016A	X	X		X	X
Code Plug, SCU	290-26100/	X	X		X	X
Signal Interface Unit (SIU)	290-26199/C1290199A	X	X		X	X
Titan Interface Unit (TIU)	290-26197/C1290197A	X	X	X		
RF Switch (2 pole)	280-41008	X	X		X	X

FIGURE 2.0
IUS/ DSP EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO DSP SEP	DSP AFTER REQD SEP	
Antenna, Omni, DOD	290-27105	--	X	Not Applicable		
Antenna, Med. Gain (NASA)	290-27106	X	X		X	X
SGLS Transponder, S Band	290-22121/C1290018A	X	X		X	X
20 Watt Amplifier, S Band	290-22117/C1290021A	X	X		X	X
Diplexer (DOD)	290-22200	X	X		X	X
Environ. Meas. Subsystem	290-22224	X	X		X	X
EMU Transducers	290-22228	X	X		X	X
Fail Safe R/F Relay	280-41009	X	--		X	X
DC Block	280-61001	X	--	X		
Avionics Battery (140 AH) (Stage 1)	290-22211/C1290023A	X	X	X		
Utility Battery (13 AH)	290-22212/C1290037A	X	X		X	X
Avionics/Spacecraft Battery (100 AH) (Stage 1)	290-22211/C1290037A	--	X	X		
Avionics Battery (170 AH)	290-22211	X	X	X		
T34D/IUS Destruct Battery	290-27001	X	--	X		
DC/DC Converter Regulator	290-22210/C1290038A	1	1	1 Optional Not on DSP 12,13		
Pyro Switching Unit (PSU)	290-26054/C1290054A	X	X	X		
Power Transfer Unit (PTU)	290-27200/C1290056A	--	X	Not Applicable		

FIGURE 2.0
IUS/ DSP EQUIPMENT LIST

NAME	BAC DWG/CI SPEC	USED ON		FUNCTION		ANALYSIS REQUIRED
		T34D	STS	PRIOR TO DSP SEP	REQD AFTER DSP SEP	
Power Distributor Unit (PDU)	290-26117/C1290017A	X	X		X	X
Isolation Diode Assy	290-26070	--	X	Not Applicable		
Temperature Sensor Assy	290-26222	X	X	X		
Separation Nuts	290-24130/C1290019A	X	X	X		
Staging Mech. (Super Zip)	290-24006/C1290053A	X	--	X		
T34D/IUS Destruct System	290-24172/C129093A	X	--	X		
Safe and Arm	290-21005	X	--	X		
Extendable Exit Cone	290-21001/CI290012A	--	X	X		
Staging (Separation) Connector	290-27412	X	--	X		
Pyro Connector	290-27412	X	--	X		

3.0 SHOCK ANALYSIS

The IUS equipment reponse to DSP induced separation shock was calculated using the following relationship.

$$S_c = TF \times S_s$$

S_c = Calculated shock spectrum at the IUS equipment location

S_s = Shock spectrum on the DSP adapter when the separation device is fired

TF = Transfer function between the DSP adapter and the IUS equipment location

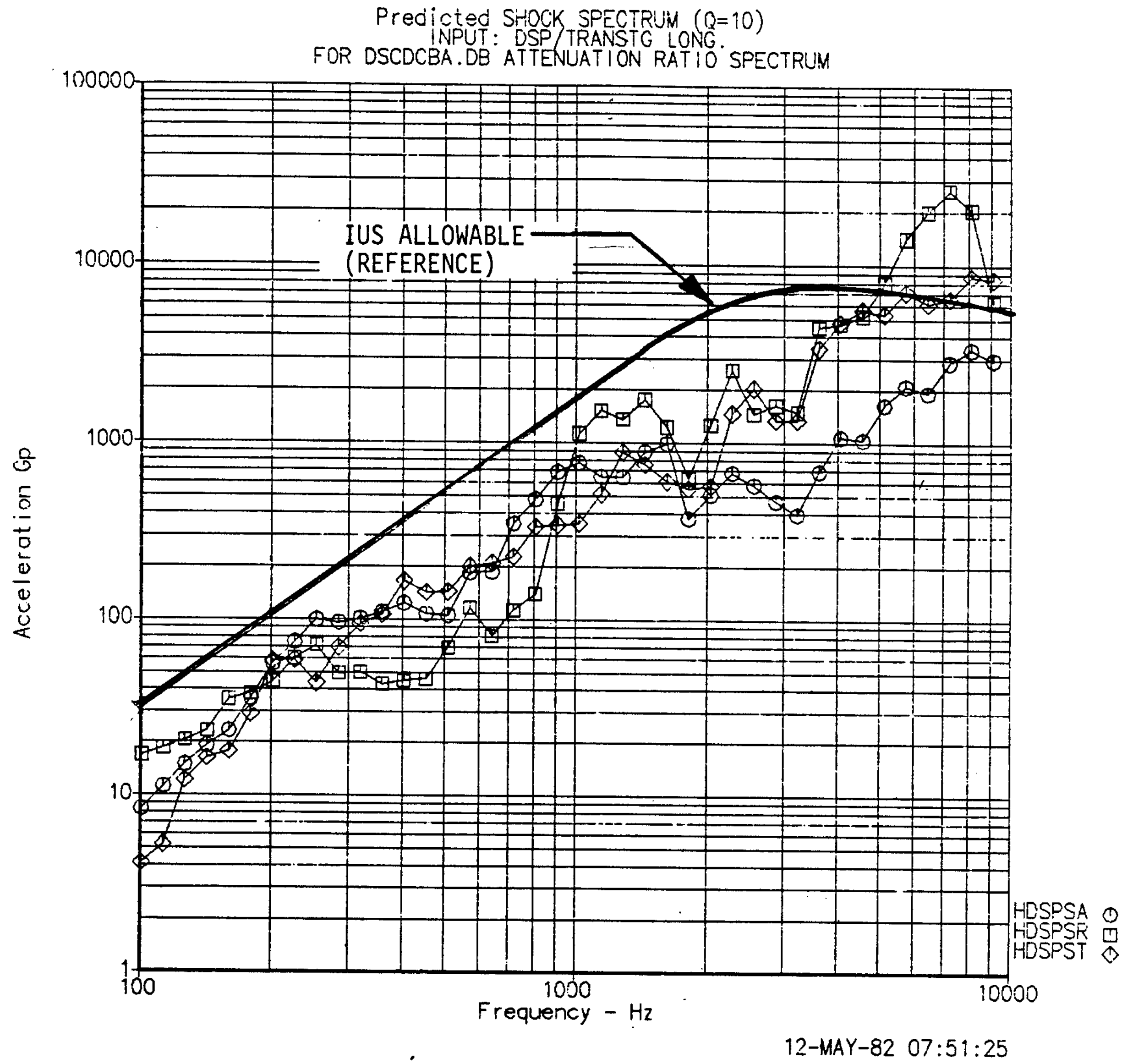
The estimated DSP adapter shock environment (S_s) is shown in Figure 3.0. This environment was derived from data obtained during the DSP satellite/AC-2 separation shock test conducted in 1970, Reference 4. The estimation procedure is discussed in Section 5.

The transfer functions between the DSP adapter attach points and the IUS equipment locations were calculated using shock data from the IUS QTV stage 1/2 separation shock test. The IUS QTV test was conducted during May 1981. The shock spectra from the test are documented in Reference 5.The transfer function calculations and calculation of the shock spectra at the IUS equipment locations were performed on a Digital Equipment Corporation, VAX 11/780 computer, The shock calculation programs were written by Fred Spann, Boeing Dynamics Staff.

The following subsections, 3.1 through 3.8, discuss the analysis details and results for the IUS equipment requiring analysis per Figure 2.0.

Reference 4. TRW Report 8713TR014-001, Spacecraft Qualification Separation Shock Test on the Defense Support Program Qualification Spacecraft, 13 July 1970.

Reference 5. Test Report No. 22B5-005R-1, Pyro Shock-Staging/Separation QTV,Volumes 1 and 2, Boeing Aerospace Co., 1 December 1981.



DSP 12, 13 INDUCED SHOCK

AT IUS/DSP INTERFACE, DSP SIDE (S_S)

O Axial
□ Radial
◇ Tangential

CALC	CB	12MAY82	REVISED	DATE	FIGURE 3.0	
CHECK						
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3.1 REM* (Rocket Engine Module) Shock Prediction

The equations and data used to predict the REM response to DSP induced shock are shown on Figure 3.1.1. The REMs are at 6 different locations on the IUS as shown on Figure 3.1.2. The predicted environments are shown in Figures 3.1.12, 3.1.13 and 3.1.14.

*BAC Drawing 290-21002/CI290020A

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GENERAL EQUATION SEE FIGURE 3.1.2

$$S_C = S_S\left(10^{\frac{-A1 - A2 - AB}{20}}\right)$$

A1 = Attenuation across Spacecraft / IUS joint
A2 = Attenuation between Ss and Sc
AB = Attenuation correction for distance.
AN19 = Attenuation between spacecraft adapter at 292.5° and REM N19 at 274°, Figure 3.1.11.

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

A1 = Attenuation across spacecraft/IUS joint
Attenuation across the DSP 12, 13 / IUS joint at IUS station 379 was estimated using shock data from the IUS DTV/CS3 spacecraft test conducted in 1980. The attenuations as a function of frequency are shown in Figure 3.1.3.

Figures 3.1.4, 3.1.5, and 3.1.6 show comparisons of attenuations at the IUS 379 interface for the IUS QTV and IUS DTV. The IUS QTV attenuation is across the joint between the top of the longeron and the 379 ring without a spacecraft attached. The IUS DTV attenuation is across the joints between the top of the IUS longeron and the CS3 spacecraft foot. The IUS DTV/CS3 data is discussed in Attachment 2 to Boeing memo 2-3964-0000-029, dated 22 Feb 1980.

Figures 3.1.7. 3.1.8 and 3.1.9 show the same comparisons as 3.1.4 thru 3.1.6 with the addition of attenuations across the AC-2/DSCS joints. The AC-2/DSCS attenuation is between the DSCS bipod foot and an AC-2 longeron location 4 inches from the interface. Note that the AC-2 transtage exhibits higher attenuations than the IUS at high frequencies in the radial and tengential directions.

A2 = Attenuation between the spacecraft attach location and the REM

Figure 3.1.10 shows A2 as a function of frequency. A2 was calculated using IUS QTV data. The attenuation was calculated as follows.

$$A2 = 20 \log \frac{\text{Mean of spacecraft attach point spectra}}{\text{Mean of REM attach point spectra}}$$

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

$\underset{\sim}{A}$ = Calculated Attenuation in decibels
$\underset{\sim}{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

B = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

Subscripts
d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies

Attenuation AB

For N19 AND N51

$$AB = 20 \log \frac{21.7 \text{ in.}}{26.6 \text{ in.}}$$

$$AB = -1.8 \text{ db}$$

For N17 and 49

$$AB = 20 \log \frac{28.8}{26.6}$$

$$AB = +0.7 \text{ db}$$

FINAL EQUATIONS

$$S_{N51} = S_{N19} = S_S\left(10^{\frac{-A1-A2+1.8}{20}}\right) \Longrightarrow$$

The predicted shock spectra are shown in Figures 3.1.12, 3.1.13, 3.1.14

$$S_{N2} = S_{N37} = S_S\left(10^{-\frac{A2-A1}{20}}\right)$$

$$S_{N17} = S_{N49} = S_S\left(10^{-\frac{A1-A2-0.7}{20}}\right)$$

FIGURE 3.1.1
REM / DSP 12,13
SHOCK EQUATIONS

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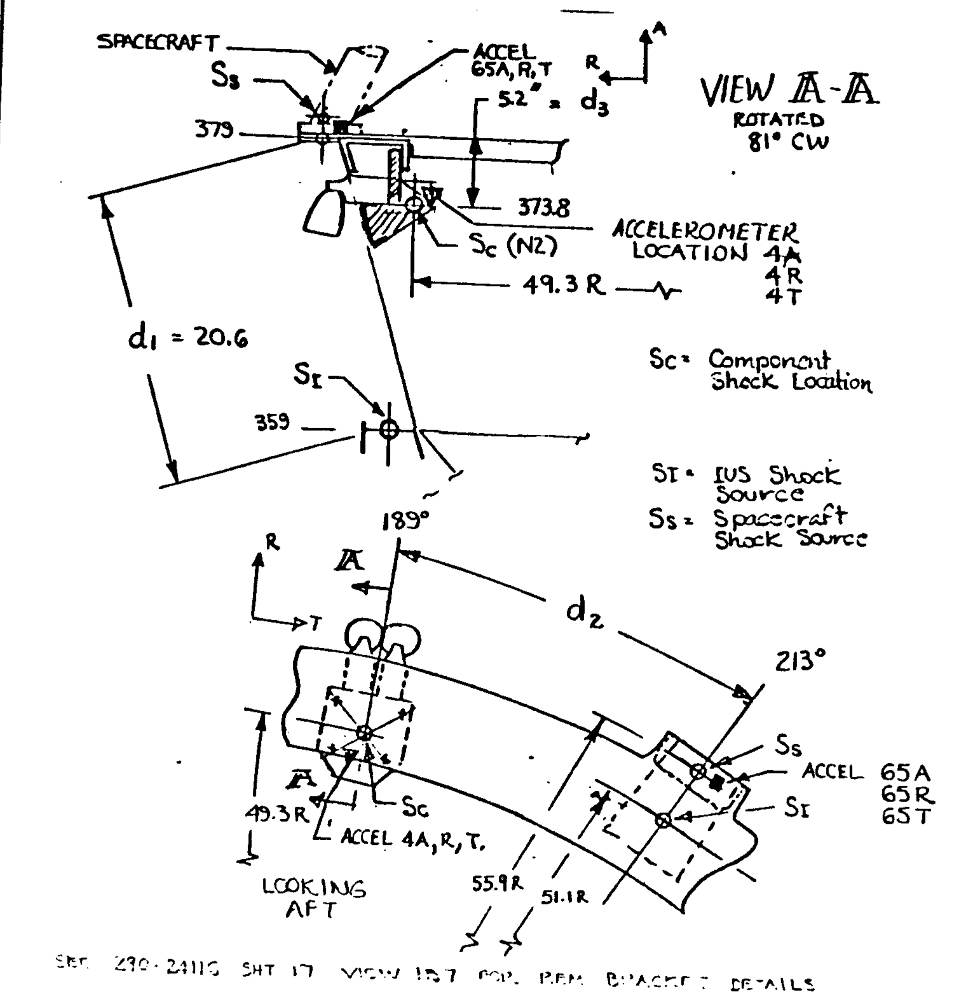
NUMBER
REV LTR



REM ID	S_C REM LOCATION X_C (IN)	Θ_C	R_C (IN)	LOCATION NEAREST SOURCE S_I IUS X_I	Θ_I	R_I	S_S S/C X_S	Θ_S	R_S	PATH LENGTH ▷ I-C	S-C
N2*	373.8	189°	49.3	359	213°	51.1	379	213°	55.9	47.2	26.6
N17		266°			247.5			292.5		42.3	28.8
N19		274°			292.5			292.5		42.3	21.7
N37		9°			33°			33°		47.2	26.6
N49		86°			67.5°			112.5		42.3	28.8
N51		94°			112.5			112.5		42.3	21.7

▷ Shock path length calculations

I-C = Path length from IUS Separation Nut to REM

$I\text{-}C \cong d_1 + d_2 + d_3 = 20.6 + \frac{|\Theta_C - \Theta_I|}{360}(2\pi R_I) + 5.2$

$I\text{-}C = 25.8 + 0.89|\Theta_C - \Theta_I|$

S-C = Path length from Spacecraft Interface Attachment to REM

$S\text{-}C \cong d_2 + d_3$

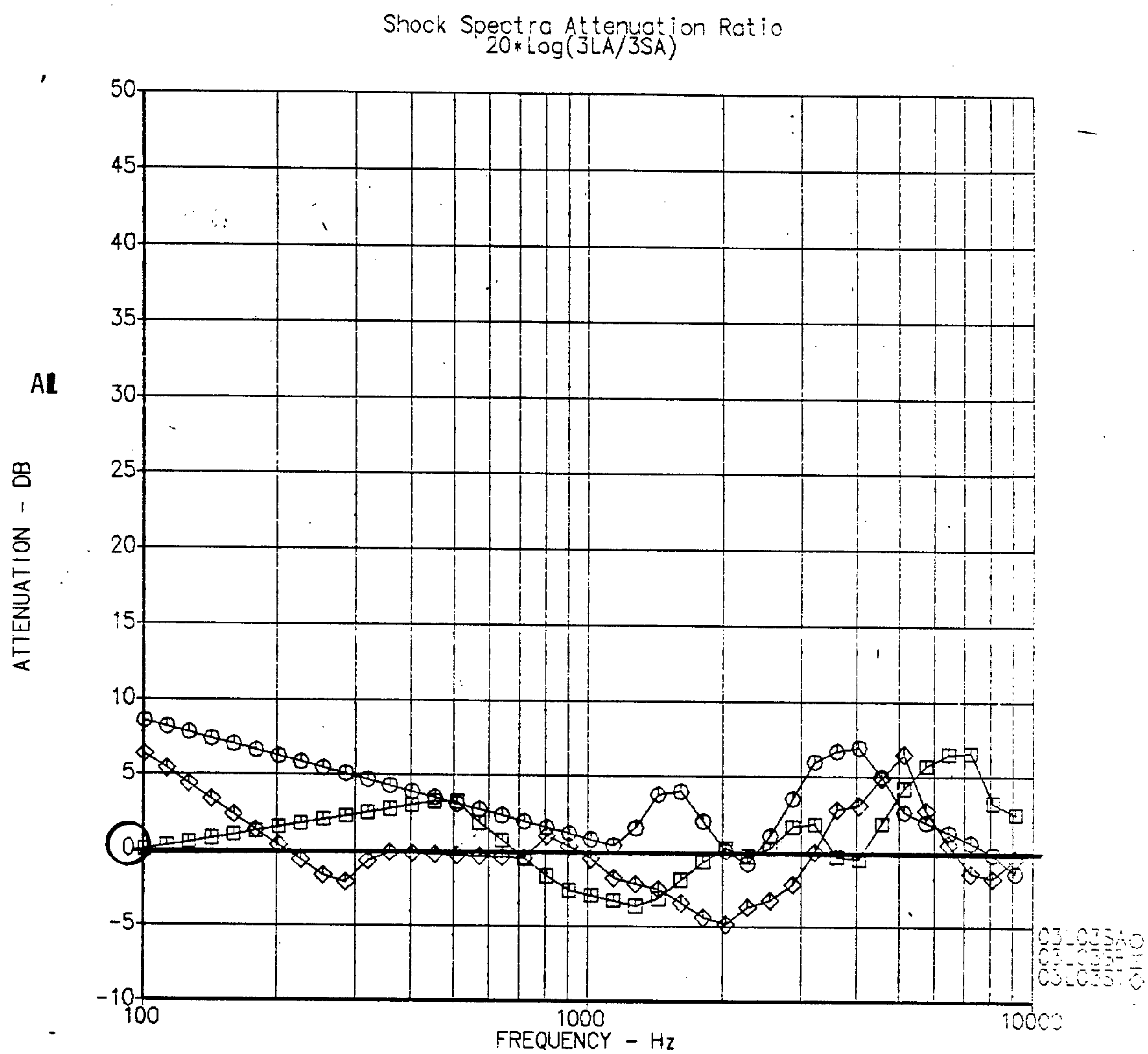
* This REM instrumented during QTV pyro shock test, Accelerometers 4A, 4R, 4T.

NOTE: DSP 12, 13 SPACECRAFT ATTACHS TO IUS AT $\Theta = 33°, 112.5°,$

FIGURE 3.1.2
REM SHOCK PATHS
DSP 12, 13

$$A1^* = C3LC3S^*.DB = 20 \log \frac{HC3L^*.ENV}{HC3S^*.ENV}$$

$*$ = A, R, or T



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ATTENUATION , A1

ACROSS IUS/DSP 12, 13 INTERFACE

○ Axial, A1A

□ Radial, A1R

◇ Tangential, A1T

CALC	CJB	5MAY82	REVISED	DATE	FIGURE 3.1.3	
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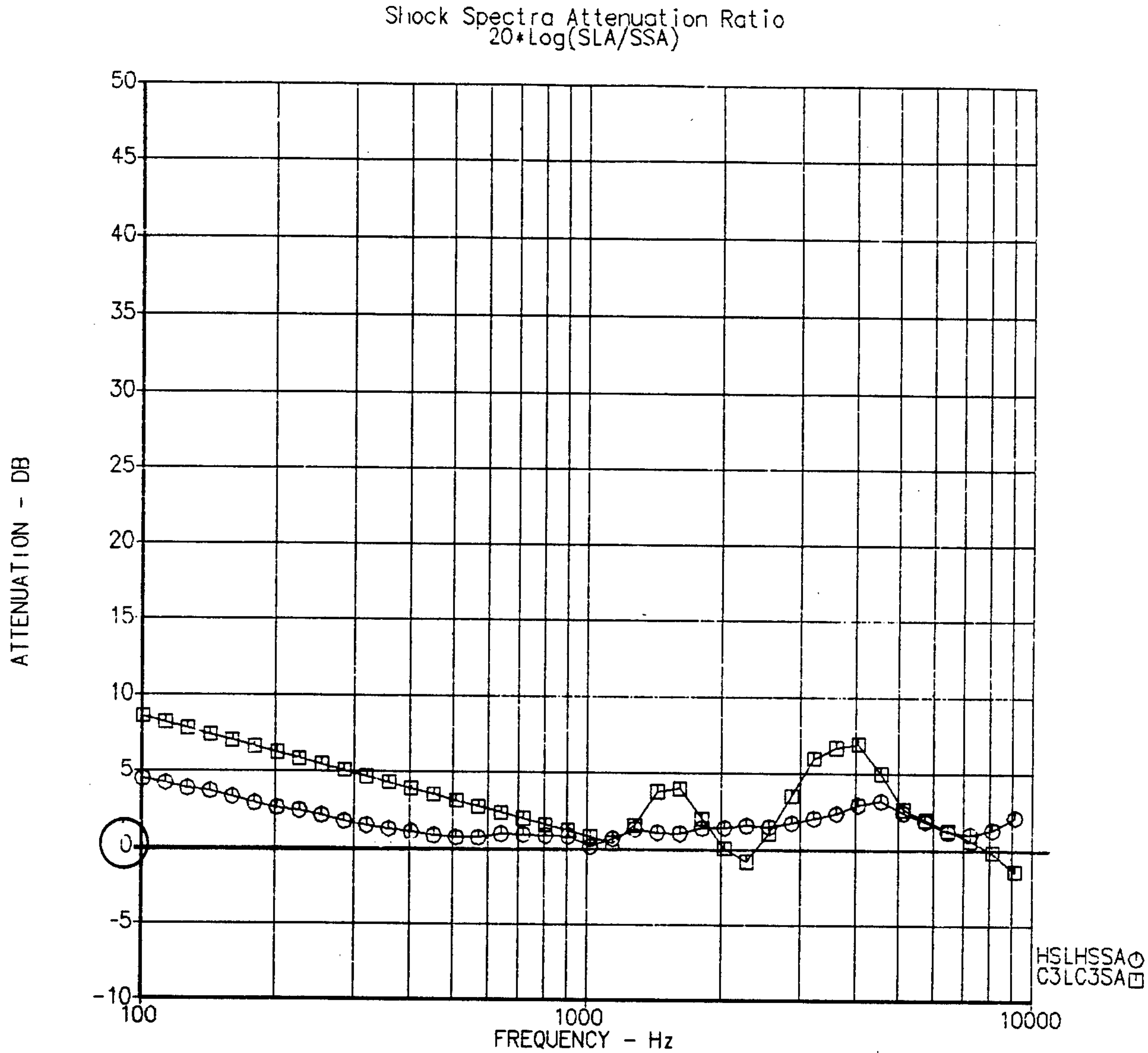
			D290-75303-2	Vol. I	THE BOEING COMPANY	PAGE D-16

A

○ $HSLHSSA.DB = 20 \log \frac{HSLA,MEA}{HSSA.MEA}$

□ $C3LC3SA.DB = 20 \log \frac{HC3LA.ENV}{HC3SA.ENV}$



ATTENUATION COMPARISON

ACROSS IUS/SPACECRAFT INTERFACE

AXIAL

○ IUS QTV/WITHOUT S/C (1981)

□ IUS DTV/CS3 (1980)

CALC	CJB	12MAY82	REVISED	DATE	FIGURE 3.1.4	
CHECK						
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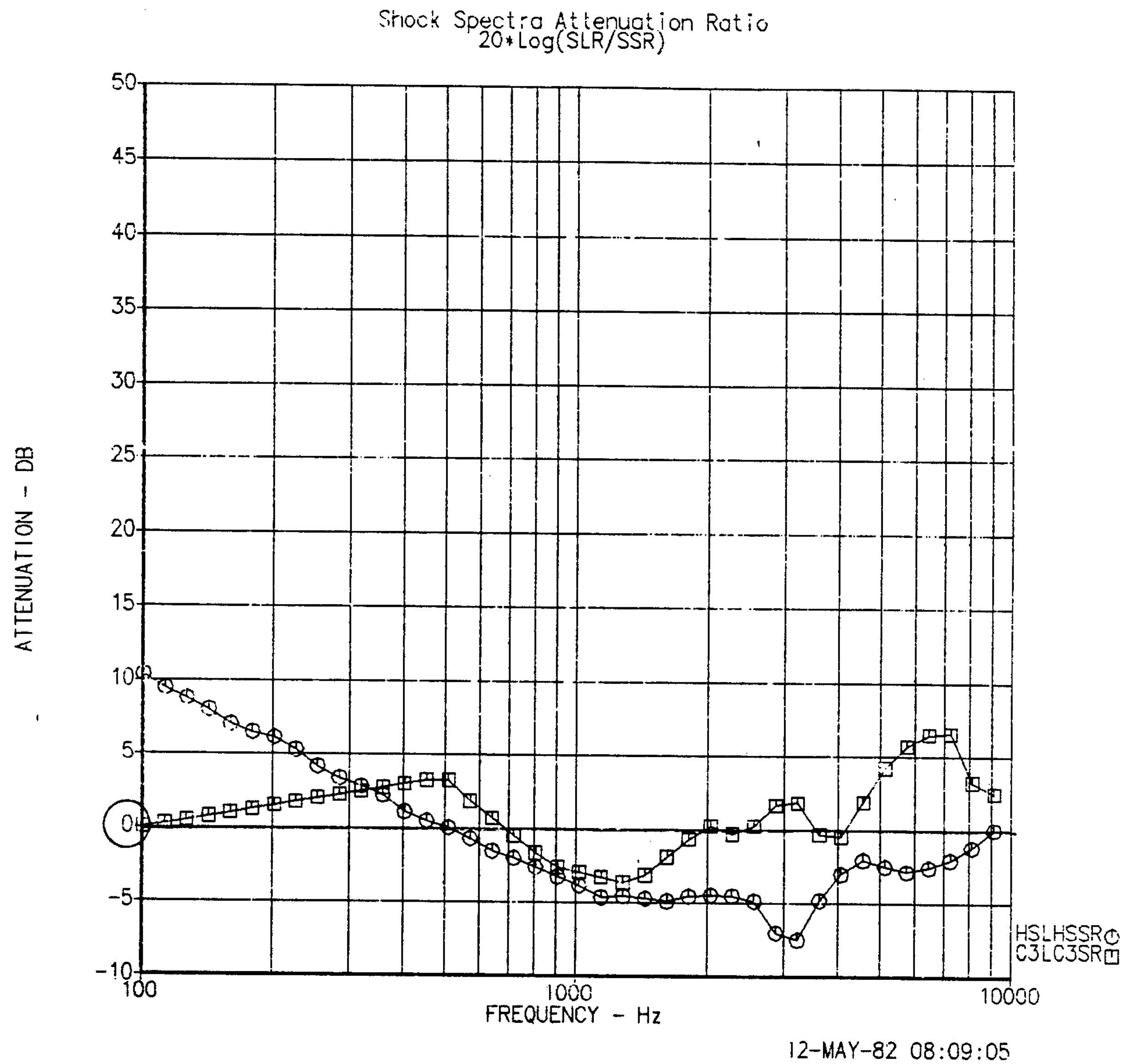
○ HSLHSSR.DB = 20 log $\frac{\text{HSLR.MEA}}{\text{HSSR.MEA}}$

□ C3LC3SR.DB = 20 log $\frac{\text{HC3LR.ENV}}{\text{HC3SR.ENV}}$



ATTENUATION COMPARISON
ACROSS IUS/SPACECRAFT INTERFACE
RADIAL

○ IUS QTV/WITHOUT SPACECRAFT (1981)
□ IUS DTV/CS3 (1980)

CALC	CAB	12MAY82	REVISED	DATE	FIGURE 3.1.5	
CHECK						
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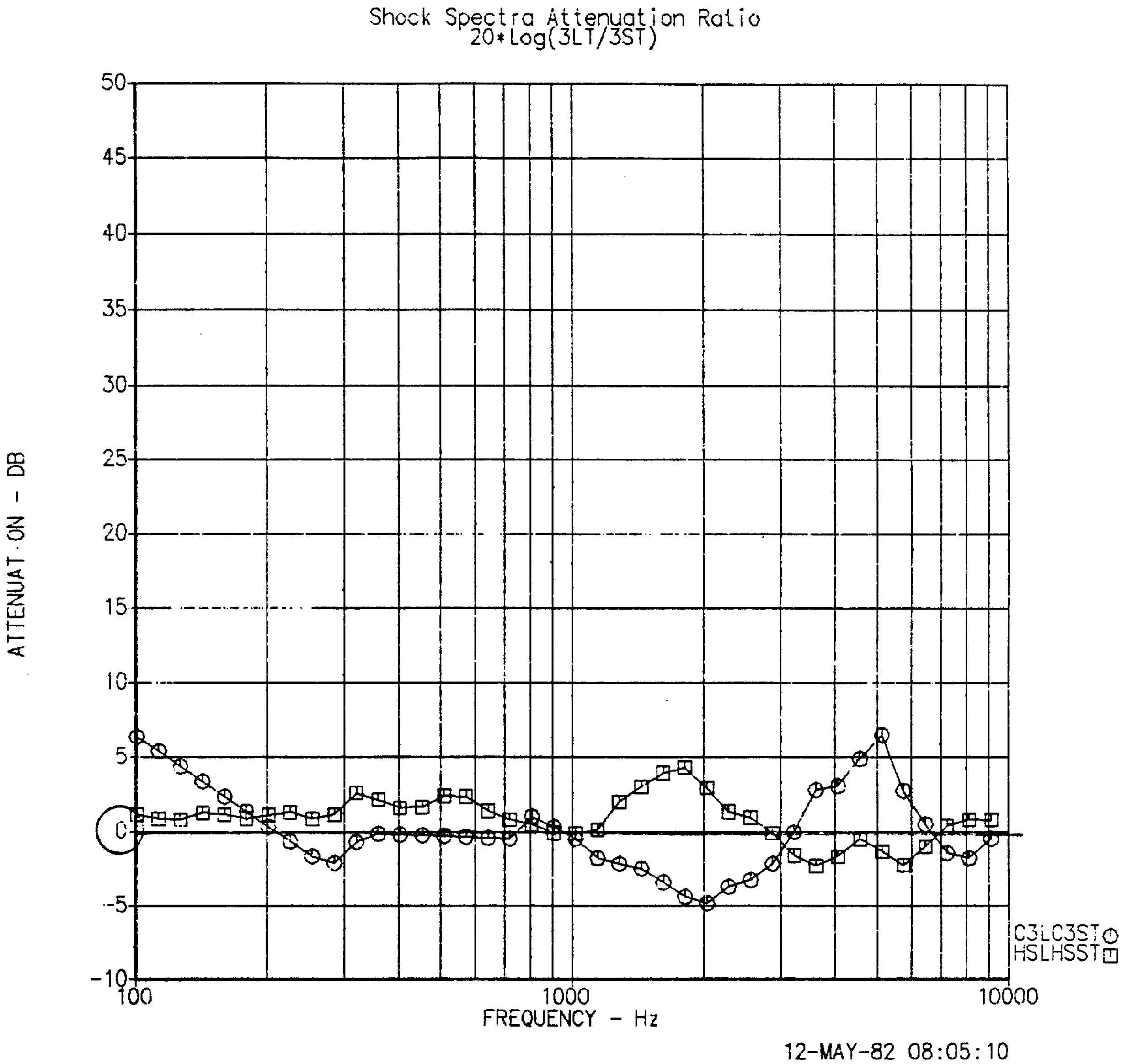
□ HSLHSST.DB = $20 \log \frac{\text{HSLT.MEA}}{\text{HSST.MEA}}$

○ C3LC3ST.DB = $20 \log \frac{\text{HC3LT.ENV}}{\text{HC3ST.ENV}}$



ATTENUATION COMPARISON
ACROSS IUS/SAPCECRAFT INTERFACE

TANGENTIAL

□ IUS QTV/WITHOUT SPACECRAFT (1981)
○ IUS DTV/ES3 (1980)

CALC		12MAY82	REVISED	DATE	FIGURE 3.1.6	
CHECK						
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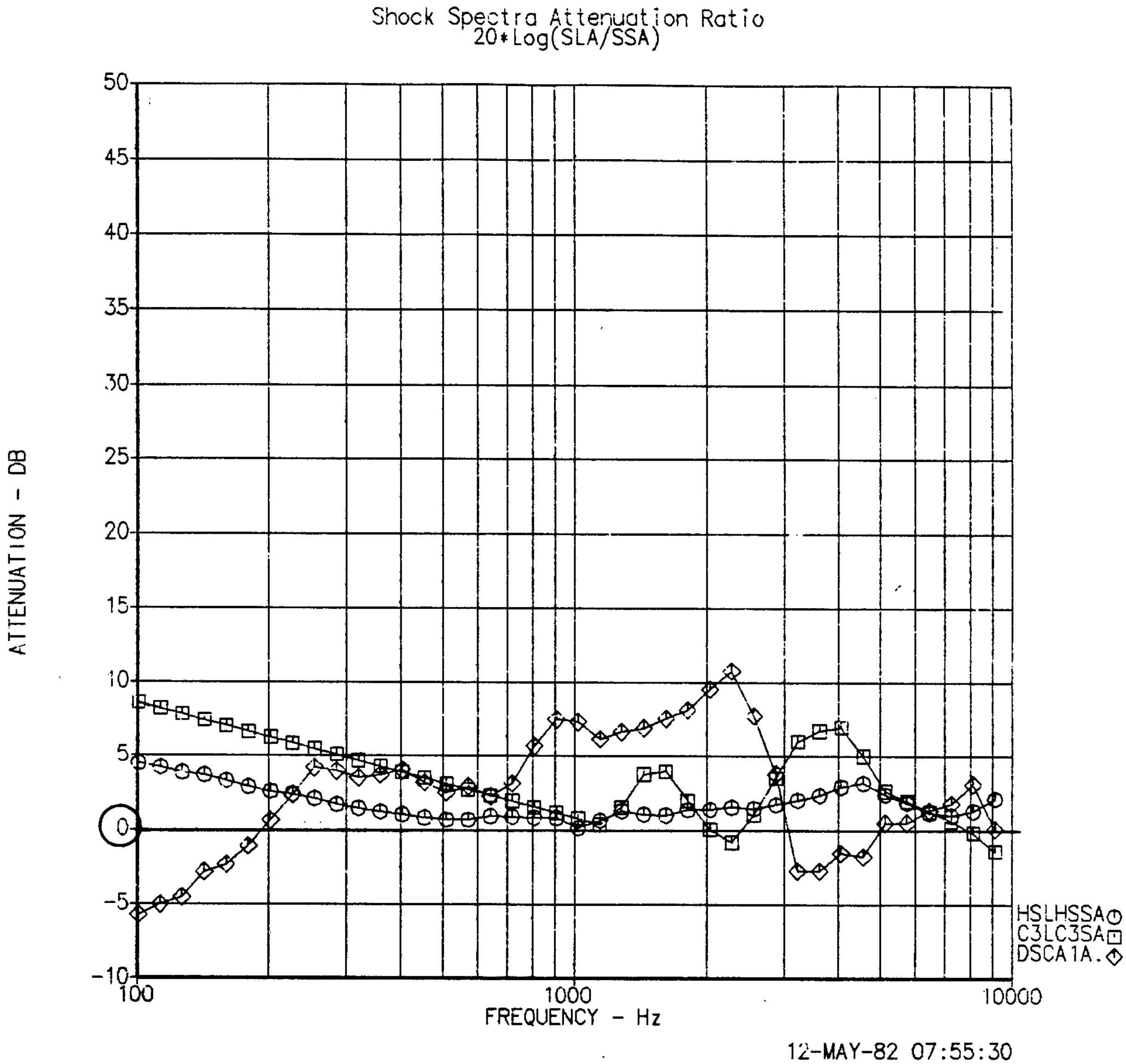
APPD.						

○ $HSLHSSA.DB = 20 \log \frac{HSLA.MEA}{HSSA.MEA}$

□ $C3LC3SA.DB = 20 \log \frac{HC3LA.ENV}{HC3SA.ENV}$

◇ $DSCA1A.DB = 20 \log \frac{HDSCBA.ENV}{HDSCSA.ENV}$



ATTENUATION COMPARISON

ACROSS LAUNCH VEHICLE/SPACECRAFT INTERFACE

AXIAL

○ IUS QTV/WITHOUT SPACECRAFT (1981)

□ IUS DTV/CS3 (1980)

◇ AC2/DSCS (1981)

CALC	CB	12MAY82	REVISED	DATE	FIGURE 3.1.7	
CHECK						
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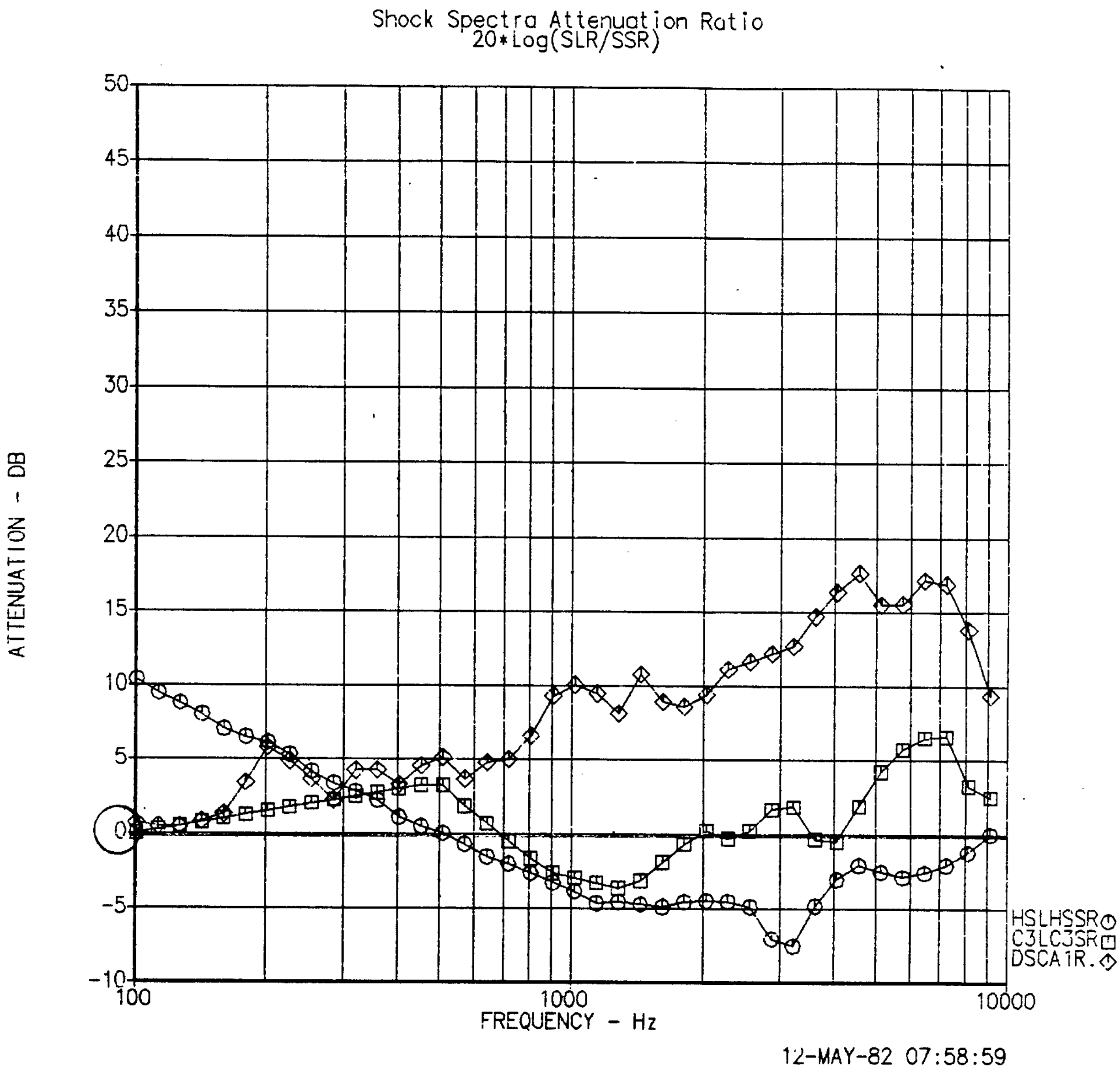
APPD.						

○ $HSLHSSR.DB = 20 \log \frac{HSLR.MEA}{HSSR.MEA}$

□ $C3LC3SR.DB = 20 \log \frac{C3LR.ENV}{C3SR.ENV}$

◇ $DSCA1R.DB = 20 \log \frac{HDSCBR.ENV}{HDSCSR.ENV}$



ATTENUATION COMPARISON

ACROSS LAUNCH VEHICLE/SPACECRAFT INTERFACE

RADIAL

○ IUS QTV/WITHOUT SPACECRAFT (1981)
□ IUS DTV/CS3 (1980)
◇ AC-2/DSCS (1981)

CALC	CB	12MAY82	REVISED	DATE	FIGURE 3.1.8	
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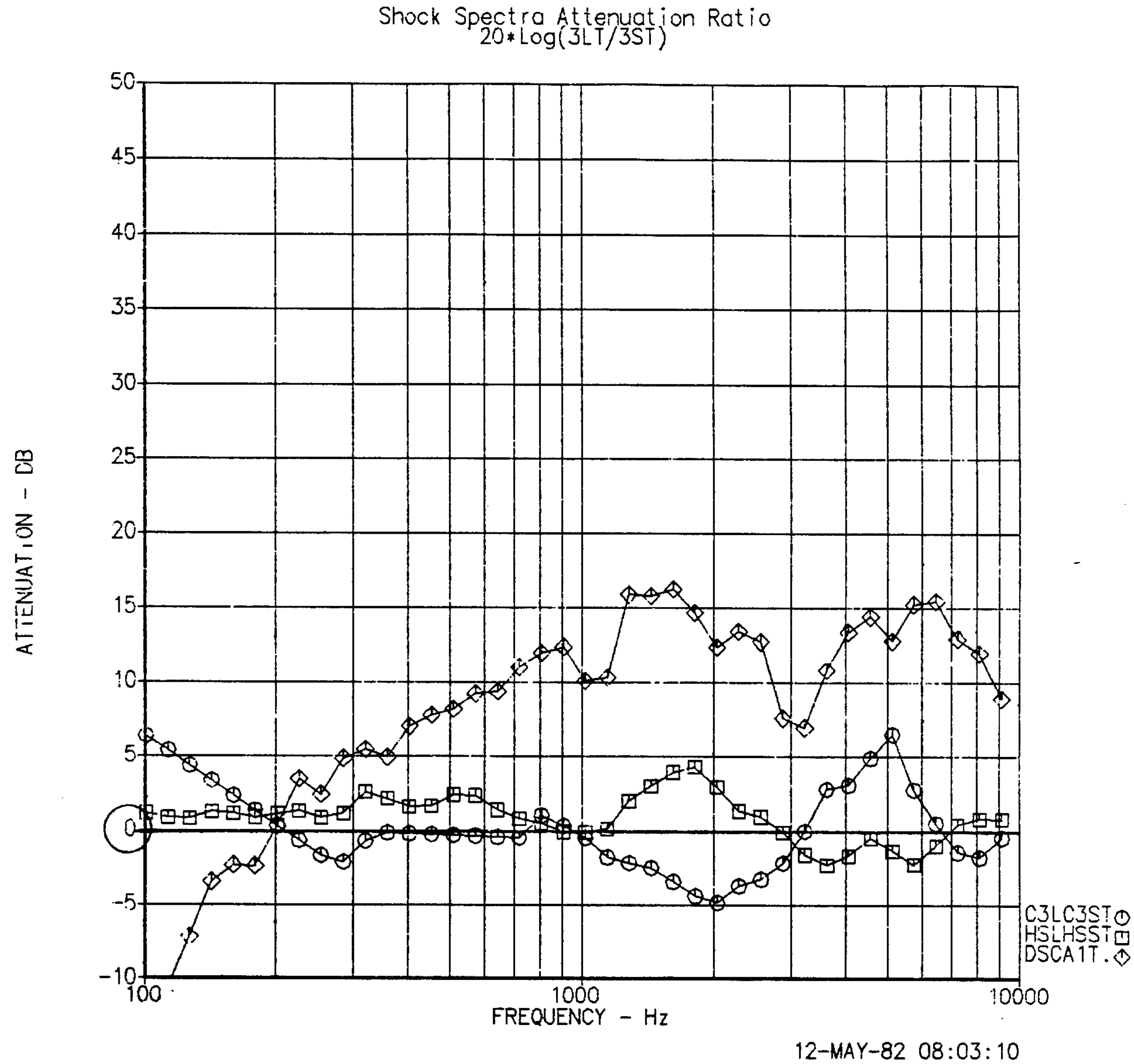
○ C3LC3ST.DB $= 20 \log \frac{HSLT.MEA}{HSST.MEA}$

□ HSLHSST.DB $= 20 \log \frac{HSLT.MEA}{HSST.MEA}$

◇ DSCA1T.DB $= 20 \log \frac{HDSCBT.ENV}{HDSCST.ENV}$



ATTENUATION COMPARISON

ACROSS LAUNCH VEHICLE/SPACECRAFT INTERFACE

TANGENTIAL

○ IUS DTV/CS3 (1980)
□ IUS QTV/WITHOUT SPACECRAFT (1981)
◇ AC-2/DSCS (1981)

CALC	CJ3	12MAY82	REVISED	DATE	FIGURE 3.1.9	
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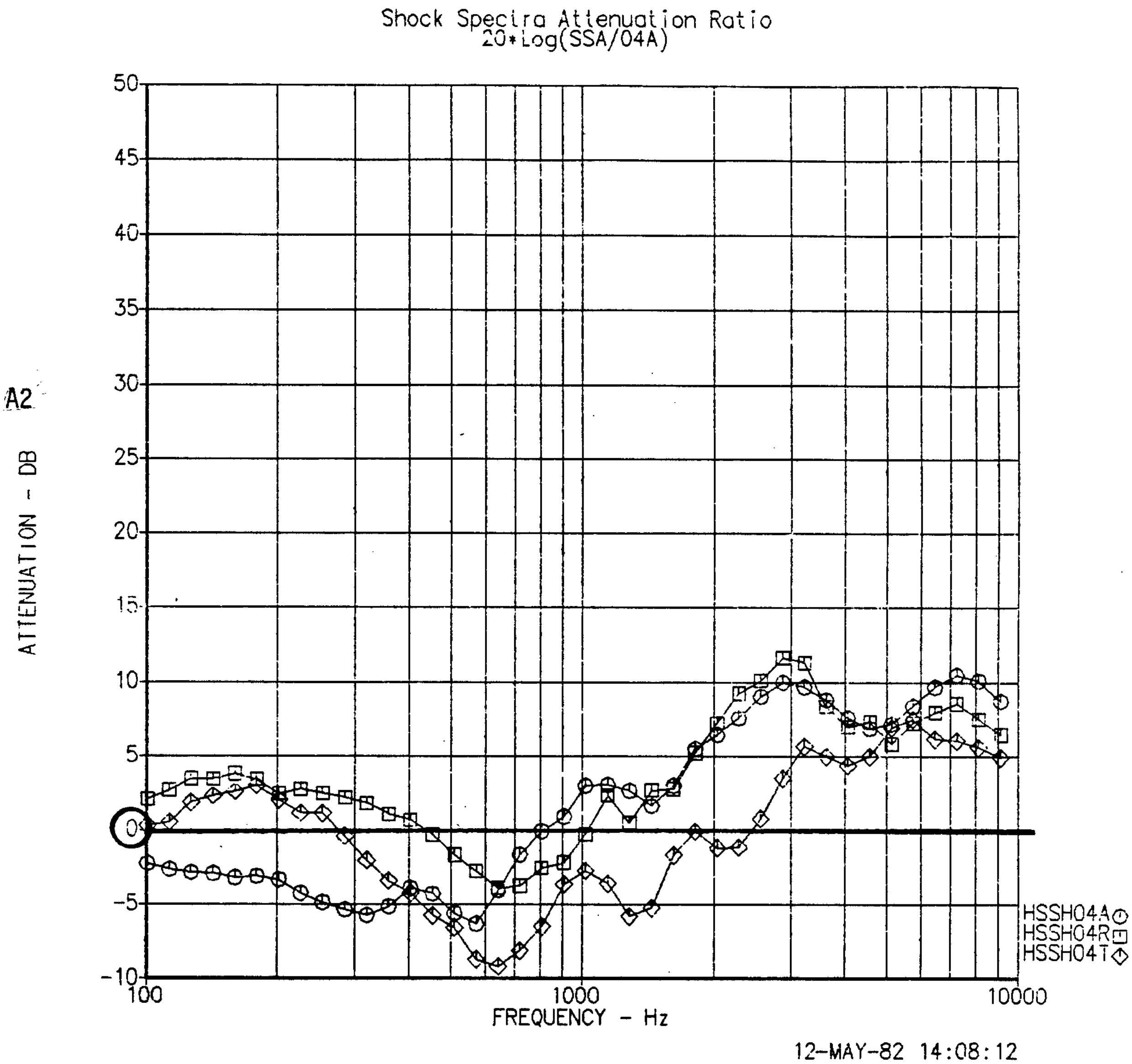
$$A2^* = HSSH04^*.DB = 20 \log \frac{HSS^*.MEA}{H04^*.MEA}$$

$* = A,R$ or T



ATTENUATION A2
SPACECRAFT ATTACH POINT @ 292.5°
TO REM, N19, @ 274°

○ Axial, A2A
□ RAdial, A2R
◇ Tangential, A2T

CALC	CB	12MAY82	REVISED	DATE	FIGURE 3.1.10	
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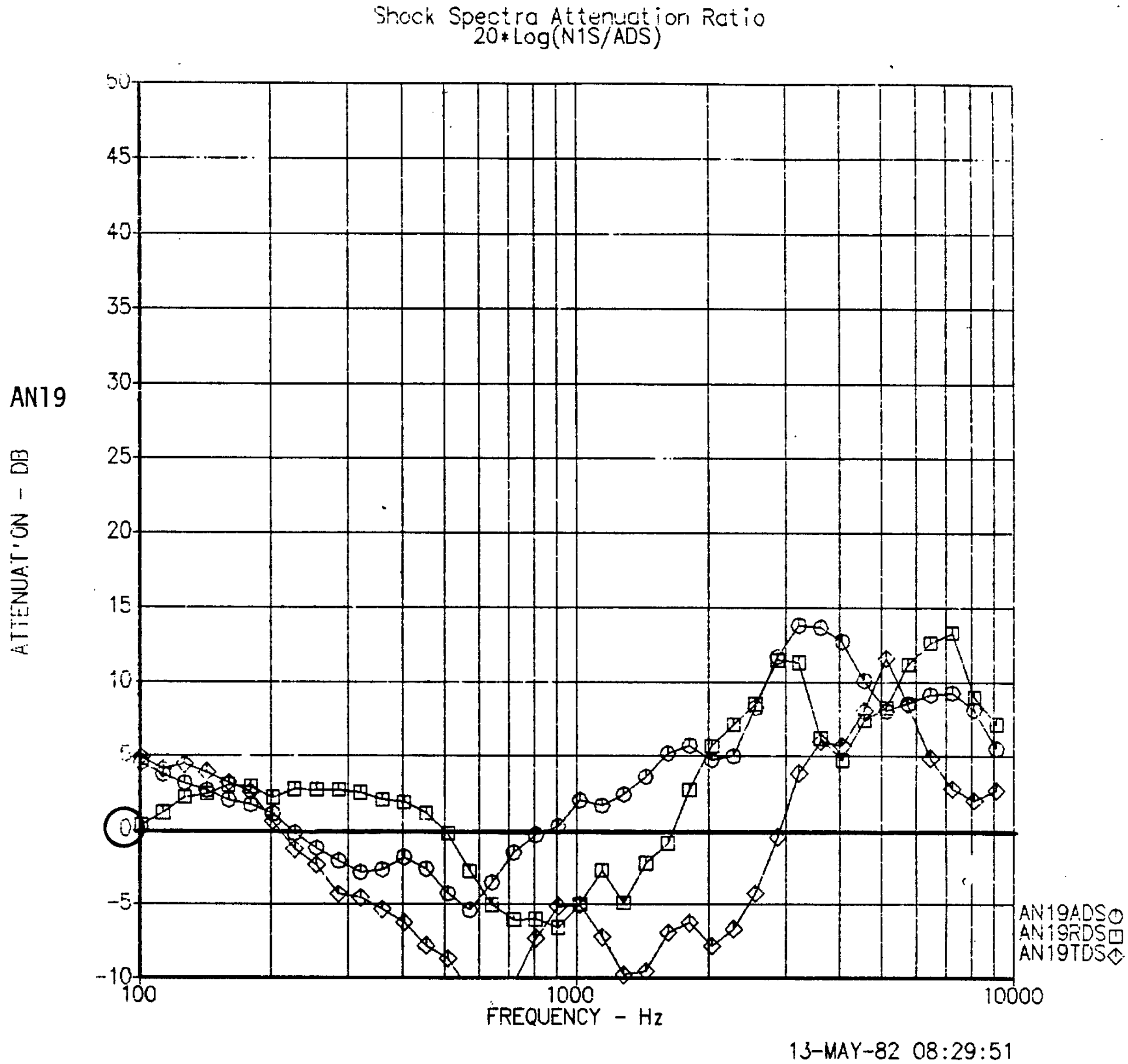
AN19* = AN19*DSP.DB = A1* + A2* - 1.8

* = A,R or T



ATTENUATION AN19

SPACECRAFT ADAPTER AT 292.5^{O}

TO REM, N19, AT 274^{O}

○ Axial, AN19A
□ Radial, AN19R
◇ Tangentil, AN19T

CALC	CB	13MAY82	REVISED	DATE	FIGURE 3.1.11	
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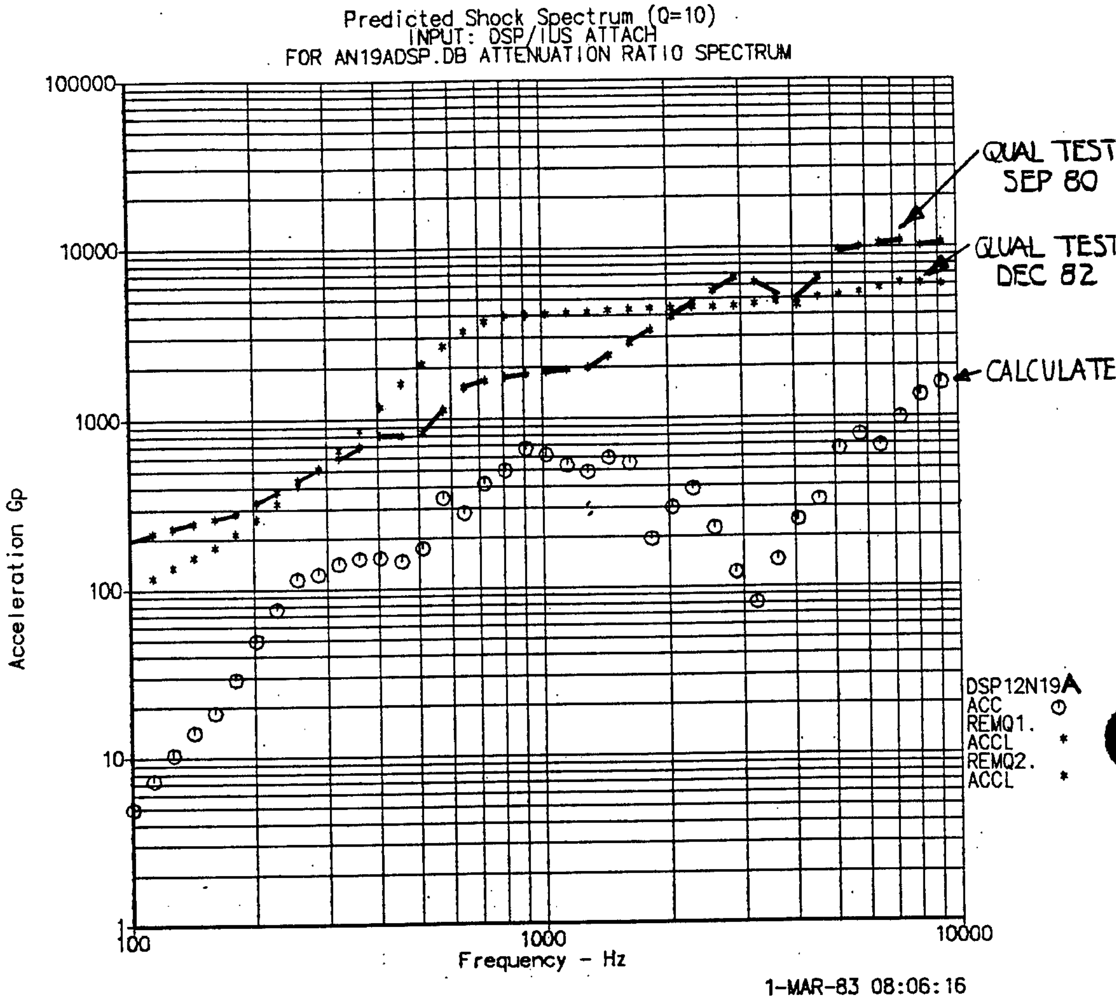
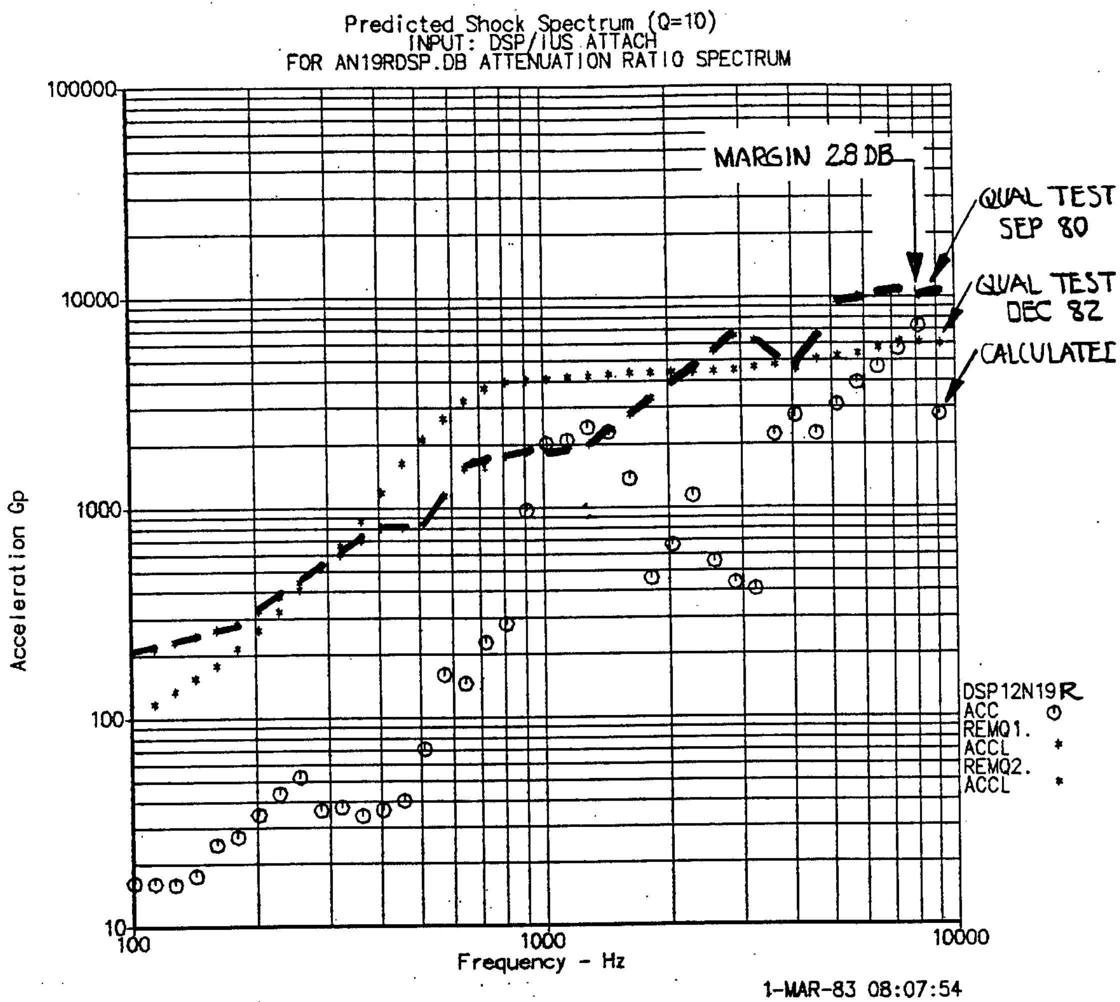
$$DSP12N19A. = S_s\left(10^{\frac{-AN19A}{20}}\right)$$



DSP 12, 13 INDUCED SHOCK
AT IUS REM LOCATION N19
0 Axial

CALC	CB	1MAR83	REVISED	DATE	FIGURE 3.1.12	
CHECK			CB	4 MAR 83		
APPD.					THE BOEING COMPANY	PAGE 25
APPD.						

$$DSP12N19R. = S_s\left(10^{\frac{-AN19R}{20}}\right)$$



DSP 12, 13 INDUCED SHOCK AT IUS REM LOCATION, N19

O Radial

CALC	CB	1MAR83	REVISED	DATE	FIGURE 3.1.13	
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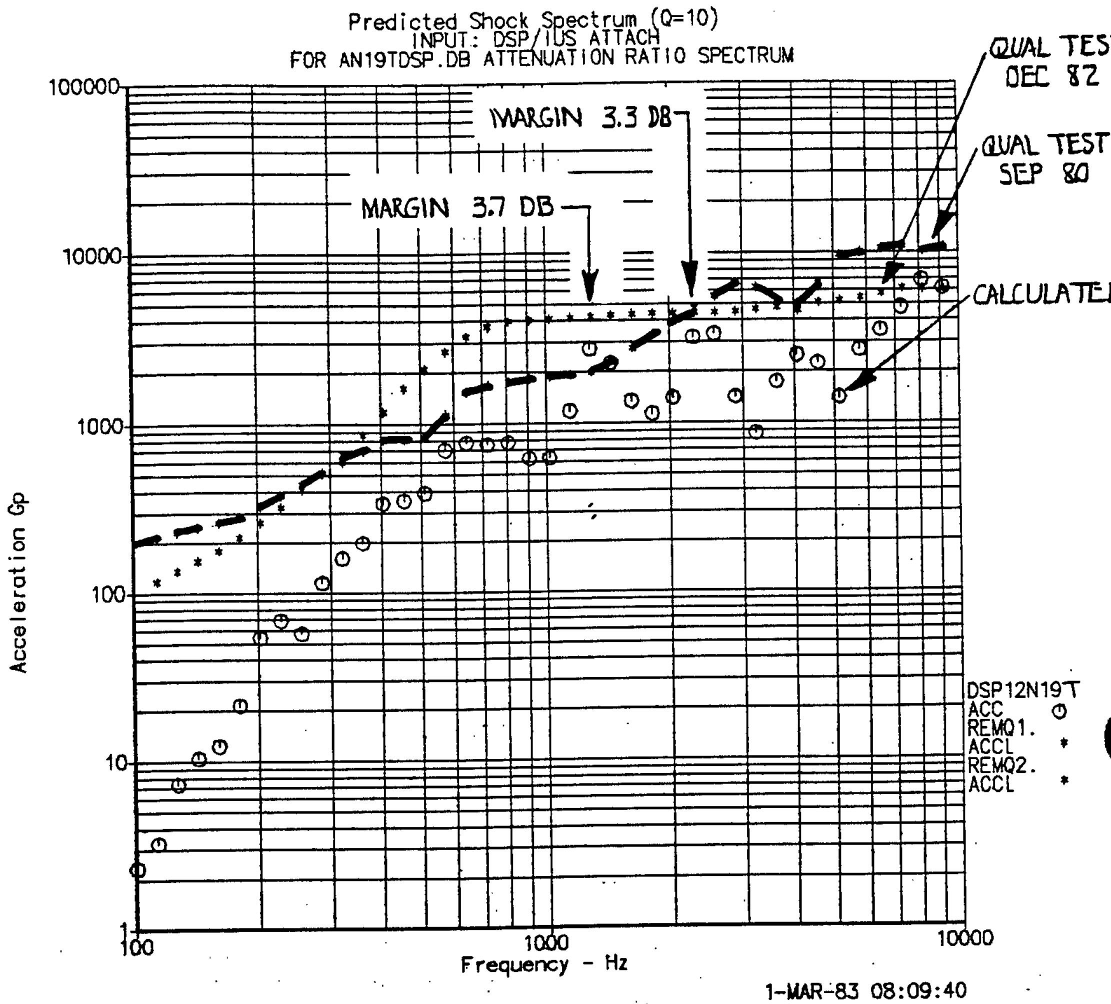
APPD.					THE BOEING COMPANY	PAGE 26

$$DSP12N19T. = S_S\left(10^{\frac{-AN19T}{20}}\right)$$



DSP 12, 13 INDUCED SHOCK
AT IUS REM LOCATION, N19
0 Tangential

CALC		1MAR83	REVISED	DATE	FIGURE 3.1.14	
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APPD.						

3.2 Computer* Shock Prediction

The equations and data used to predict the computer response to DSP induced shock are shown on Figure 3.2.1. Computers are mounted on the outer conic at two different locations shown on Figure 3.2.2. The predicted computer environments are shown in Figures 3.2.6 and 3.2.7.

*BAC Drawing 290-22119/Ci290025A

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GENERAL EQUATION

SEE FIGURE 3.2.2

$$S_C = S_S \left(10^{\frac{-A1 - A3 - A4}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, see Figures 3.1.3

A3 = Attenuation between ESS Longeron and Computer/IUS interface.

A4 = Attenuation across Computer shock isolators.

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.2.3

$$A3 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{CINd})_f}$$

Assumes S_I same at all longerons.
Shock path ≈ 7 in.

QTV ACCELS.	
S_I	S_{CIN}
1 AR (292.5°)	6 AR (140°)
70 AR (67.5°)	75 AR (140°)

See Figure 3.2.4

$$A4 = 20 \log \frac{(\bar{S}_{CINd})_f}{(\bar{S}_{COUTd})_f}$$

QTV ACCELS.	
S_{CIN}	S_{COUT}
6AR	5A
75 AR	71R

See Figure 3.2.5

$$AN15 = A1 + A3 + A4$$

FINAL EQUATIONS

$$S_{N15} = S_S\left(10^{-\frac{A1-A3-A4}{20}}\right) \Longrightarrow$$ Predicted shock spectra shown in Figures 3.2.6, 3.2.7

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

IN = Input at computer/IUS attach point

OUT = Output on computer side of shock isolator

FIGURE 3.2.1
COMPUTER
SHOCK EQUATIONS

THE BOEING COMPANY

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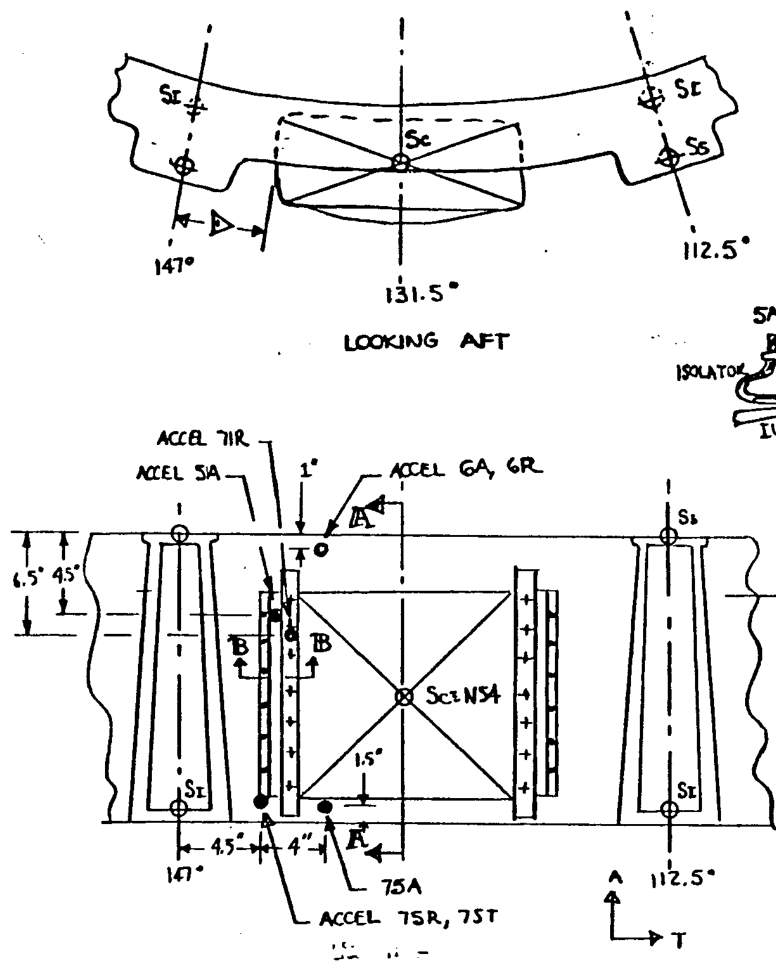
REV LTR

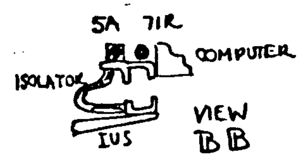
ID	COMPUTER LOCATION			SOURCE NEAREST COMPONENT						PATH LENGTH	
				SI ~ IUS			Ss ~ S/C				
	Xc	θc	Rc	XI	θI	RI	Xs	θs	Rs	I-C	S-C
N15	367	228.5	53	359	213°	51.1	379	213°	55.9	7 in.	7 in
N54	367	131.5	53	359	147°	51.1	379	112.5°	55.9	7 in.	10 in.

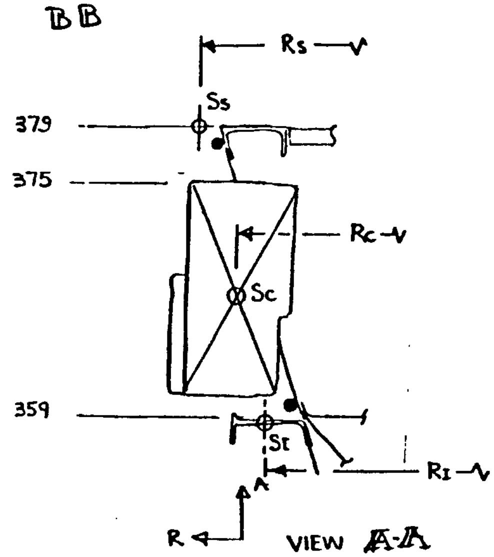
I-C = Shortest path from IUS Separation Nut (SI) to Computer / IUS Interface

S-C = Path from Ss to Sc

QTV Instrumentation on Computer N54
6A, 6R, 75A, 75R, 75T ON IUS SIDE OF SHOCK ISOLATOR
5A, 71R ON COMPUTER SIDE OF SHOCK ISOLATOR







Sc = Component Geometric Center

SI = IUS Shock Source

Ss = Spacecraft Shock Source

R = Radius or Radial

θ = Azimuth

X = Axial Station

NOTE – DSP attachs to IUS at θ = 33°, 112.5°, 213° and 292.5°

FIGURE 3.2.2
COMPUTER SHOCK PATHS

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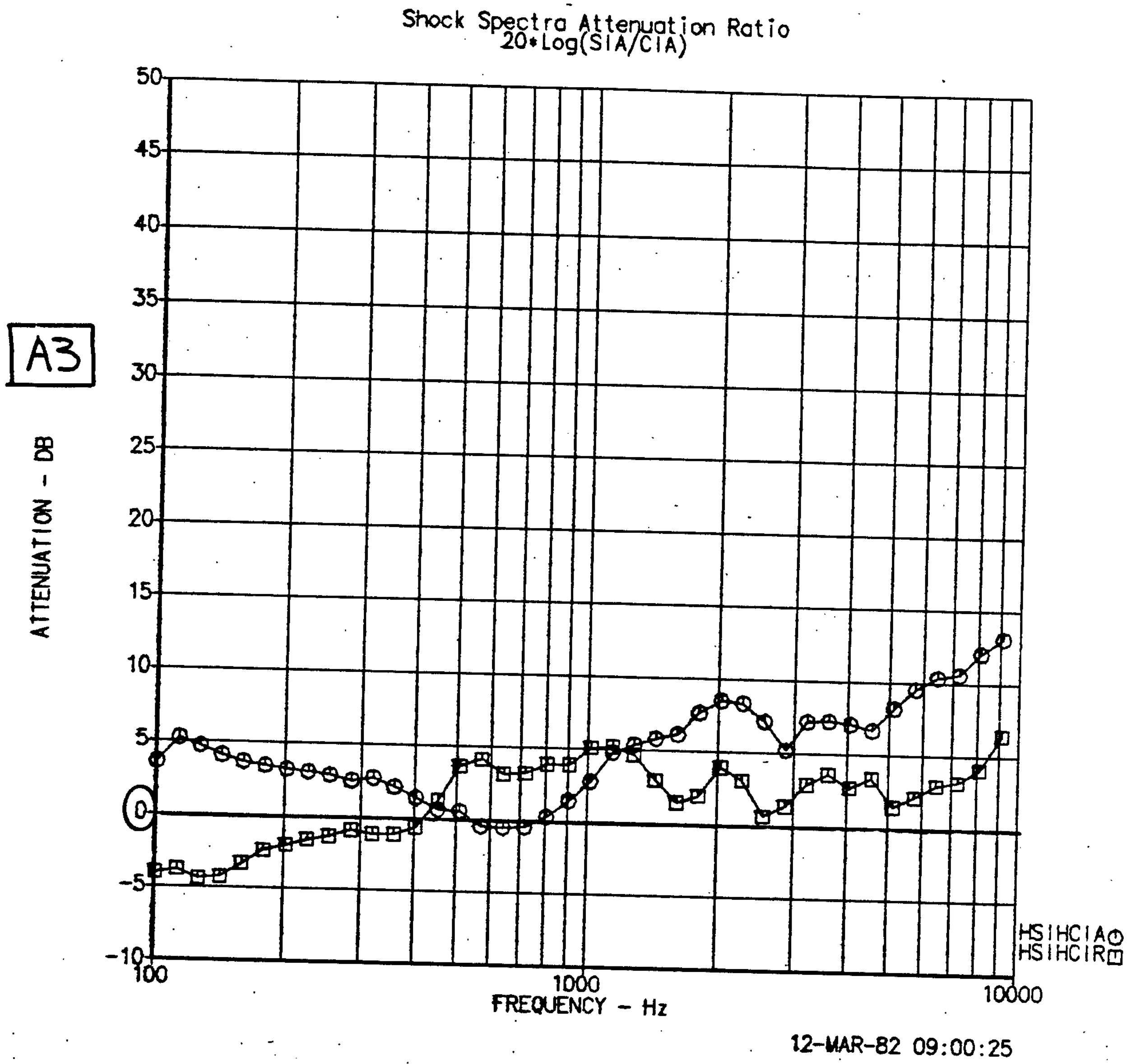
O Attenuation A3A (Axial) (HSIHCIA.DB)
□ Attenuation A3R (Radial) (HSIHCIR.DB)



ATTENUATION A3
ESS LONGERON TO COMPUTER/IUS INTERFACE
AXIAL
RADIAL

CALC	CB	12MAR82	REVISED	DATE	FIGURE 3.2.3	
CHECK						
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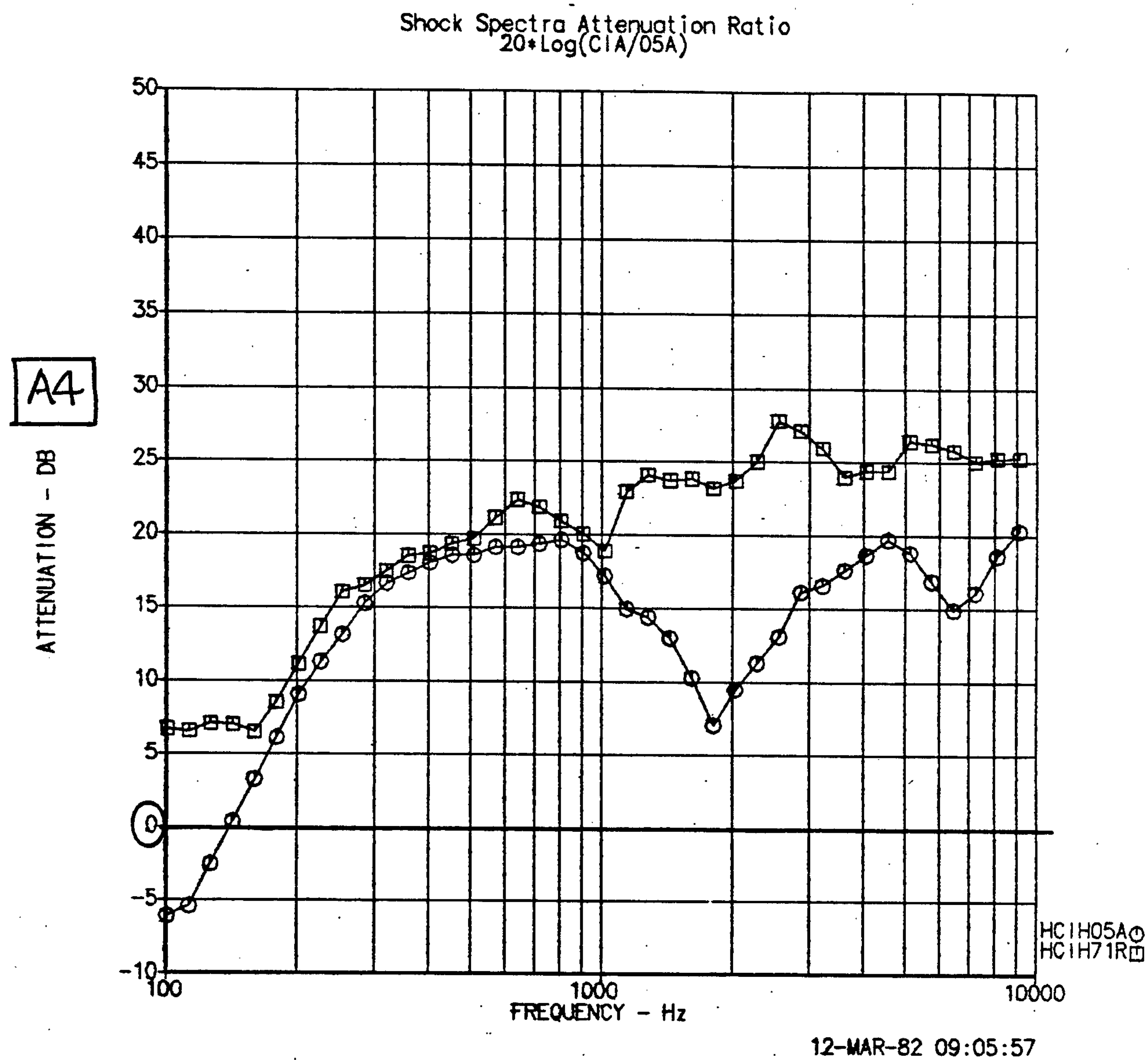
APPD.					THE BOEING COMPANY	PAGE D-31

o Attenuation A4A (Axial) = HCIH05A.DB
□ Attenuation A4R (Radial) = HCIH71R.DB



ATTENUATION A4
ACROSS COMPUTER SHOCK ISOLATORS

AXIAL
RADIAL

CALC	CB	12MAR82	REVISED	DATE	FIGURE 3.2.4		
CHECK							
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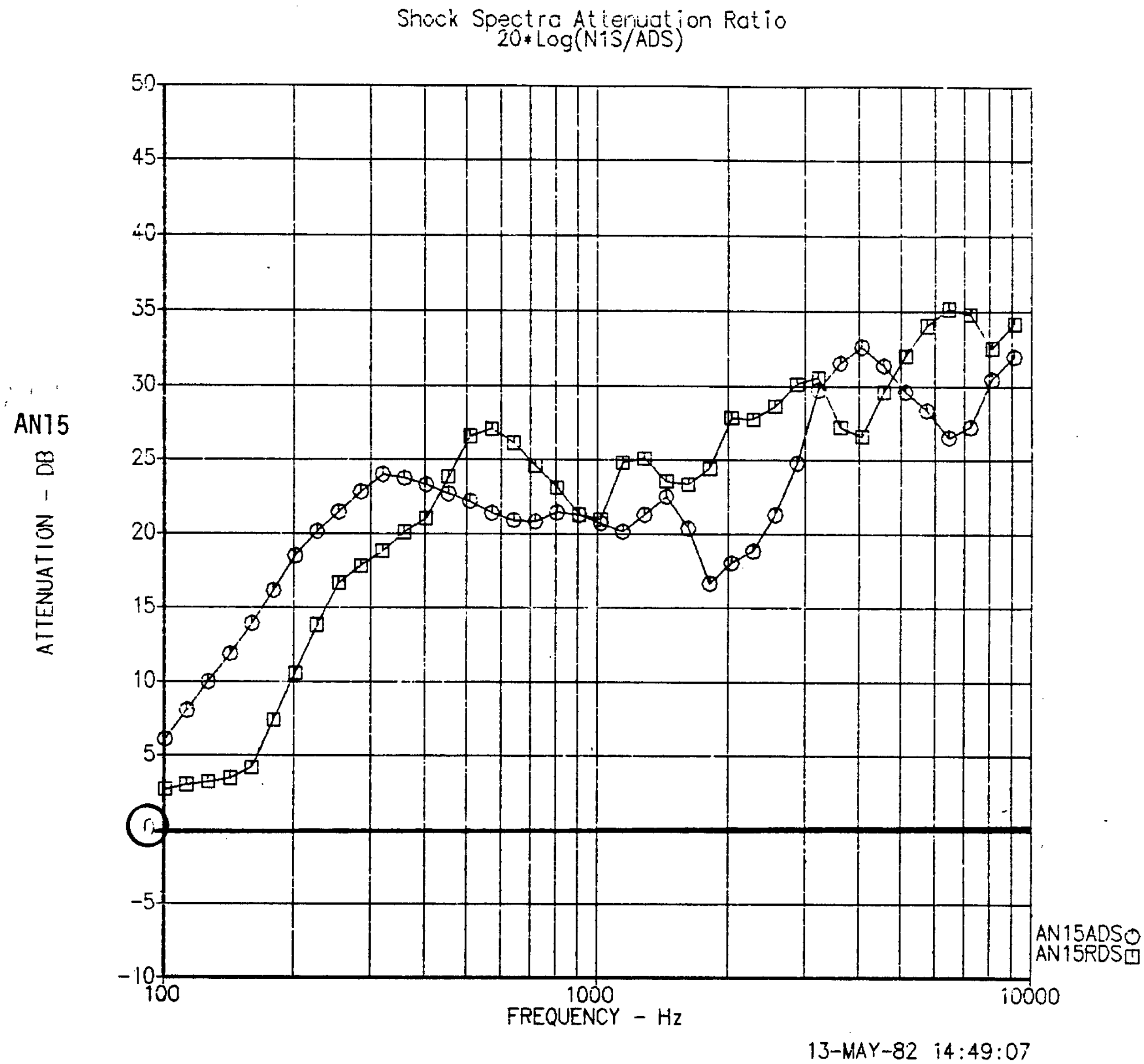
APPD.							

AN15* = AN15*DSP.DB = A1* + A3* + A4*

* = A,R or T



ATTENUATION AN15

SPACECRAFT ADAPTER @ 213°

TO COMPUTER, N15, AT 228.5°, ISOLATED SIDE

Axial, AN15A
RAdial, AN15R
Tangential, AN15T

CALC	QB	13MAY82	REVISED	DATE	FIGURE 3.2.5	
CHECK						
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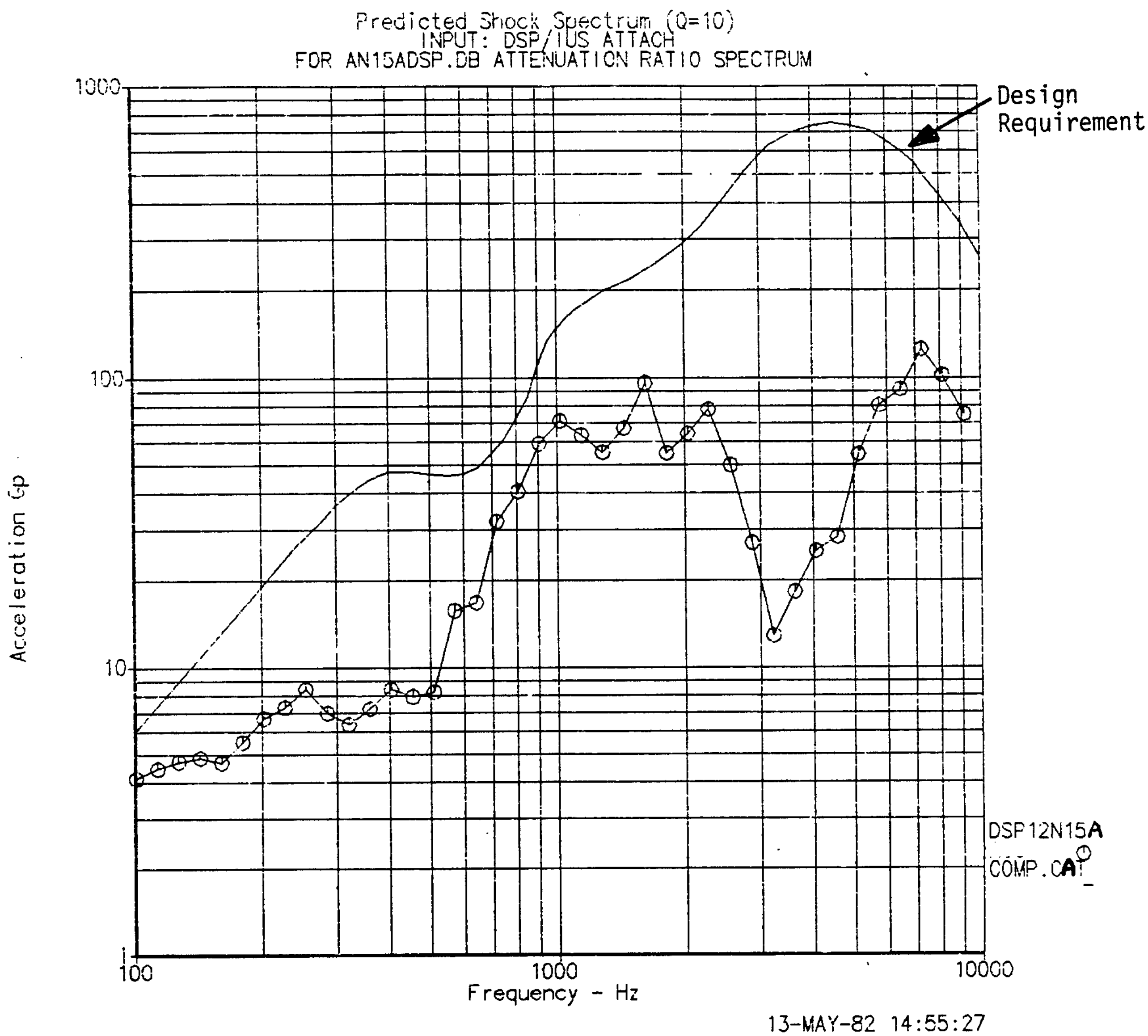
APPD.					THE BOEING COMPANY	PAGE D-33

O DSP12N15A. = $S_s(10^{-AN15A/20})$

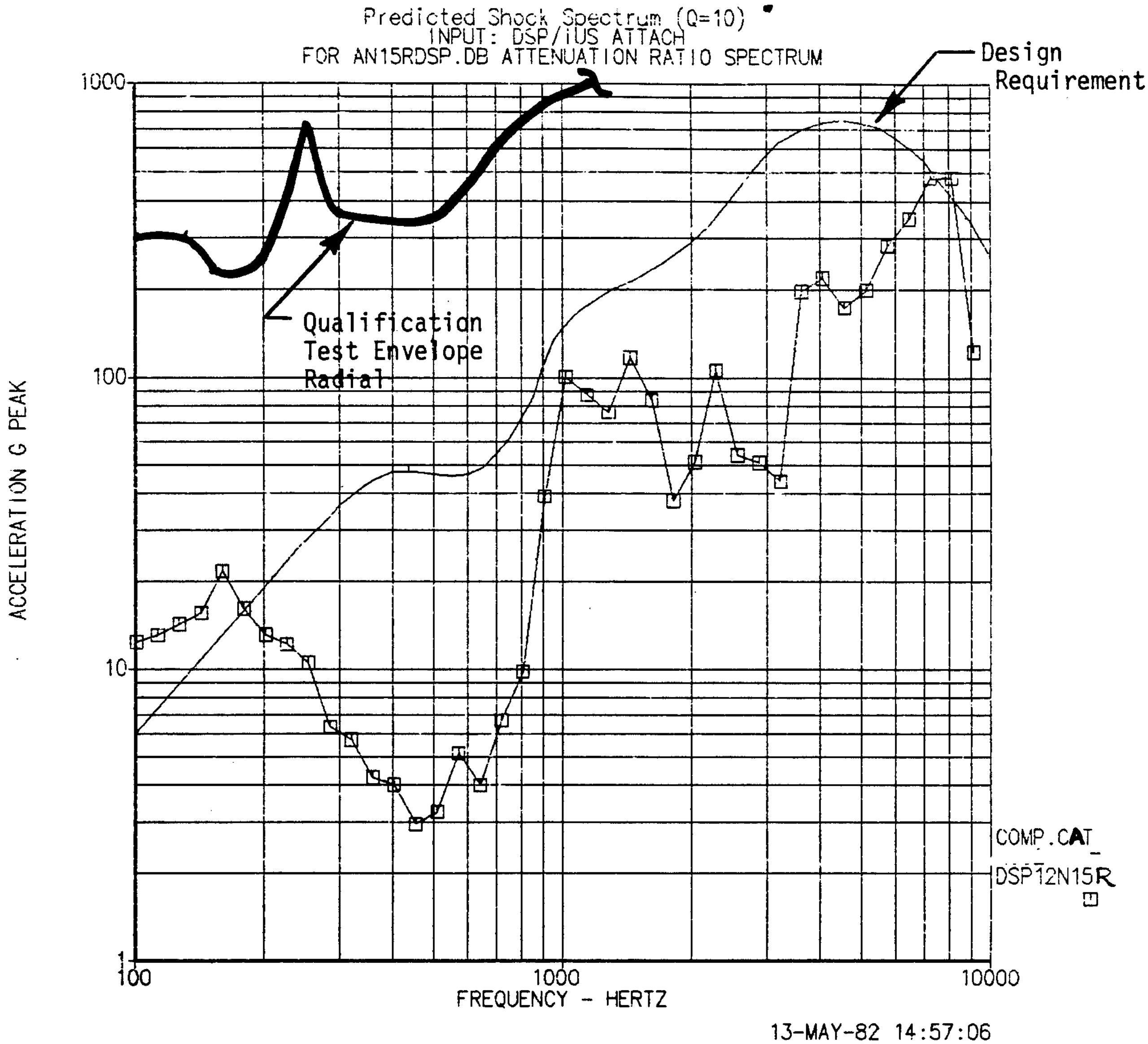


DSP 12,13 INDUCED SHOCK
AT BASE OF COMPUTER (ISOLATED SIDE)

O Axial

CALC	CB	13MAY82	REVISED	DATE	FIGURE 3.2.6	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-34

$$DSP12N15A. = S_s \, (10^{-AN15R/20})$$



DSP 12,13 INDUCED SHOCK

AT BASE OF COMPUTER (ISOLATED SIDE)

☐ Radial

CALC	OS	13MAY82	REVISED	DATE	FIGURE 3.2.7	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-35

3.3 20 Watt Amplifier* Shock Prediction

The equations and data used to predict the power amplifier response to DSP induced shock are shown on Figure 3.3.1. The amplifiers are at two locations on the outer conic as shown in Figure 3.3.2. The predicted environments are shown in Figure 3.3.6.

*BAC Drawing 290-22121/CI290018A

GENERAL EQUATION

SEE FIGURE 3.3.2

$$S_c = S_s\left(10^{-\frac{A1-A5-A6}{20}}\right)$$

A1 = Attenuation across spacecraft / IUS joint, see Figures 3.1.3.

A5 = Attenuation between ESS Longeron and Power Amp. (N28) / IUS Interface

A6 = Attenuation across Power Amp shock isolators.

APPLICABLE ACCELEROMETERS / EQUATIONS / DATA

See Figure 3.3.3

$$A5 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{CINd})_f}$$

Assumes S_I same at all longerons
Shock path 6 in.

QTV ACCELS.	
S_I	S_{CIN}
1 AR (292.5°)	76 AR (332°)
70 AR (67.5°)	

See Figure 3.3.4

$$A6 = 20 \log \frac{(\bar{S}_{CINd})_f}{(\bar{S}_{COUTd})_f}$$

QTV ACCELS	
S_{CIN}	S_{COUT}
23 AR	40 AR
76 AR ▷	73 AR ▷

▷ Not used in calculation

FINAL EQUATIONS

$$S_{N30} = S_s\left(10^{-\frac{A1-A5-A6}{20}}\right) \Longrightarrow$$

Predicted shock spectra are shown in Figure 3.3.6

Calculations for N30 only since it is closest to shock source
d = A, R

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies
IN = Input at Power Amplifier / IUS attach point
OUT = Output on Power Amplifier Side of shock isolator

See Figure 3.3.5

$AN30 = A1 + A5 + A6$
This attenuation represents the 6 inch shock path between the longeron at 327° and the power amp at 338° (N28). Since DSP does not attach at 327°, the attenuation AN30 is a low estimate.

FIGURE 3.3.1
POWER AMPLIFIERS SHOCK EQUATIONS

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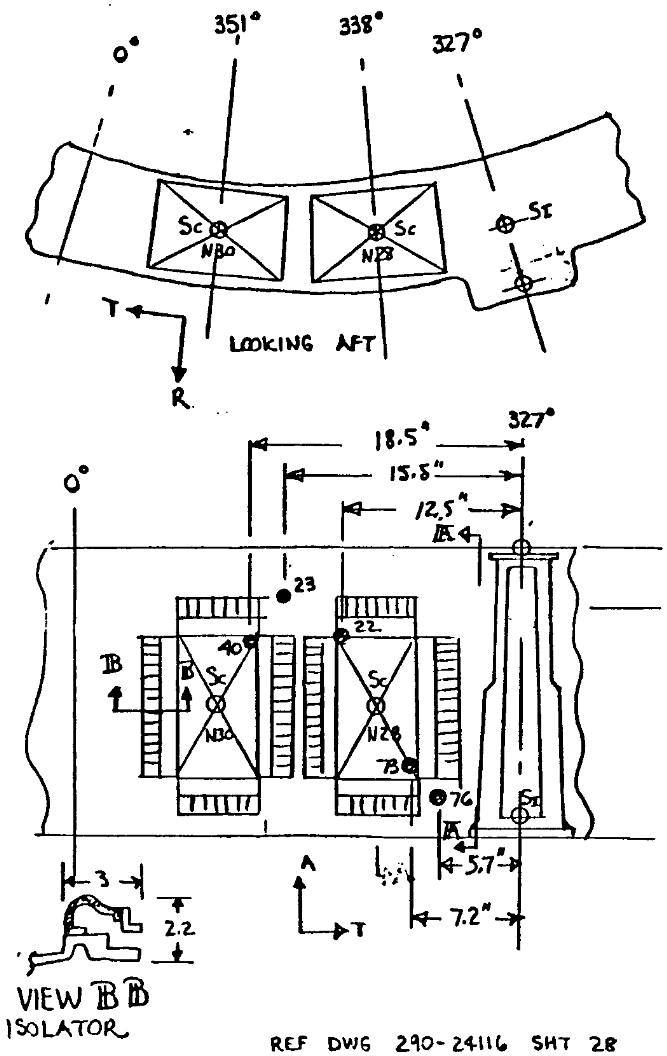
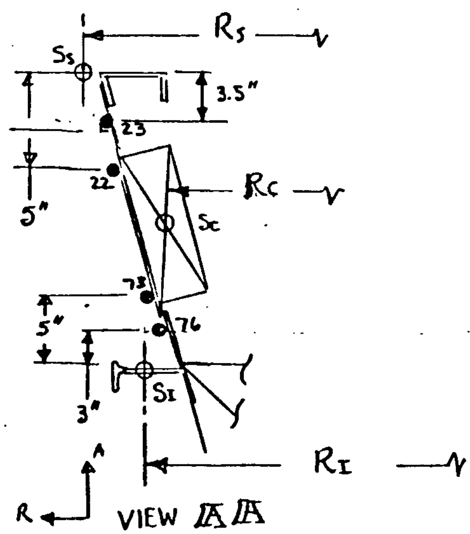
NUMBER
REV LTR

ID	Power Amplifier Location			Source Nearest Component						Path Length ▷1	
				S_I IUS			S_S S/C				
	X_C	Θ_C	R_C	X_I	Θ_I	R_I	X_S	Θ_S	R_S	I-C	S-C
N28 (A)	369	338°	50.5	359	327°	51.1	379	292.5°	55.9	6"	47"
N30 (B)	369	351°	50.5	359	327°	51.1	379	33°	55.9	16"	37"

▷1 I-C = Path from IUS Sep Nut to Power Amp / IUS Interface
S-C = Path from Ss to Power Amp / IUS Interface

QTV Instrumentation
22A, 22R, 73A, 73R on N28 Side of Shock Isolator
40A, 40R, 40T on N30 Side of Shock Isolator
{23A, 23R, 76A, 76R, 76T} on IUS side of Shock Isolator





REF DWG 290-24116 SHT 28

Sc = Component Geometric Center

SI = IUS Shock Source
Ss = Spacecraft Shock Source
R = Radius
Θ = Azimuth
X = Axial Station

NOTE: DSP attaches to IUS at
Θ = 33°, 112.5°, 213°, 292.5°

FIGURE 3.3.2
POWER AMPLIFIER
SHOCK PATHS

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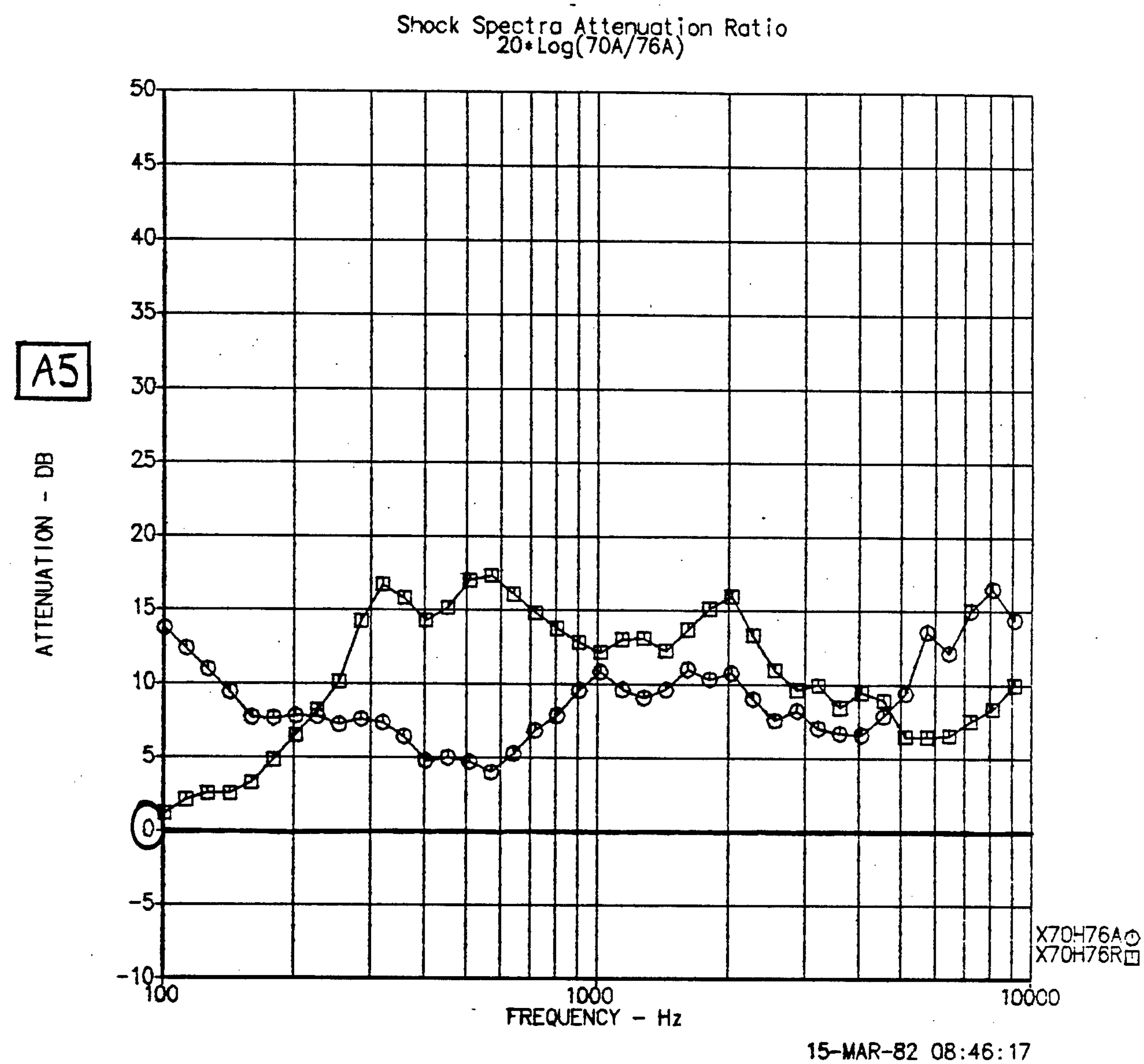
o Attenuation A5A (Axial) = X70H76A.DB
□ Attenuation A5R (Radial) = X70H76R.DB



ATTENUATION A5

ESS LONGERON TO POWER AMP/IUS INTERFACE

AXIAL
RADIAL

CALC	CB	15MAR82	REVISED	DATE	FIGURE 3.3.3	
CHECK						
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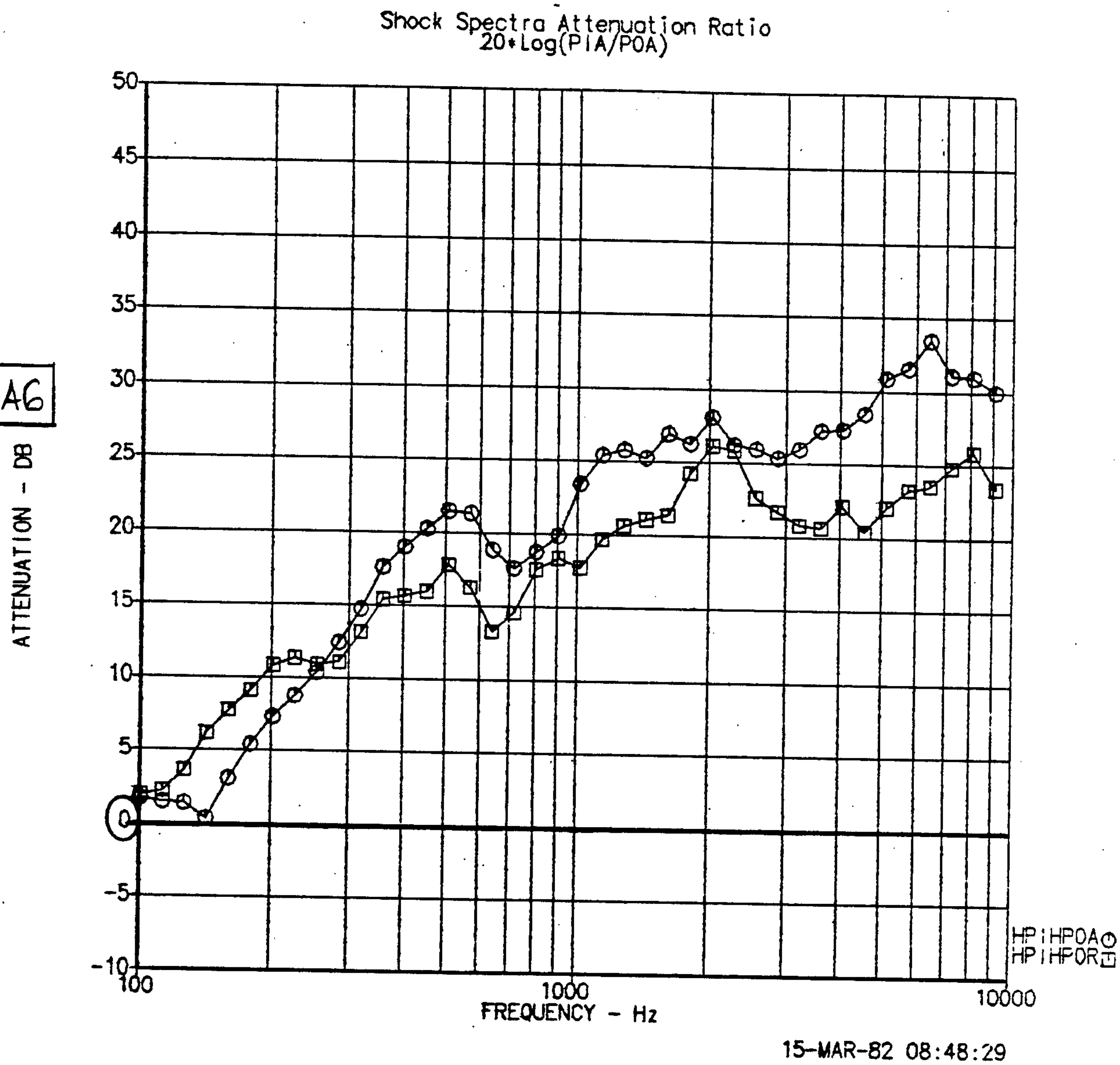
APPD.						

o Attenuation AGA (Axial) = HPIHPOA.DB
□ Attenuation AGR (Radial) = HPIHPOR.DB



ATTENUATION A6
ACROSS POWER AMP SHOCK ISOLATORS

CALC	ep	15MAR82	REVISED	DATE	FIGURE 3.3.4	
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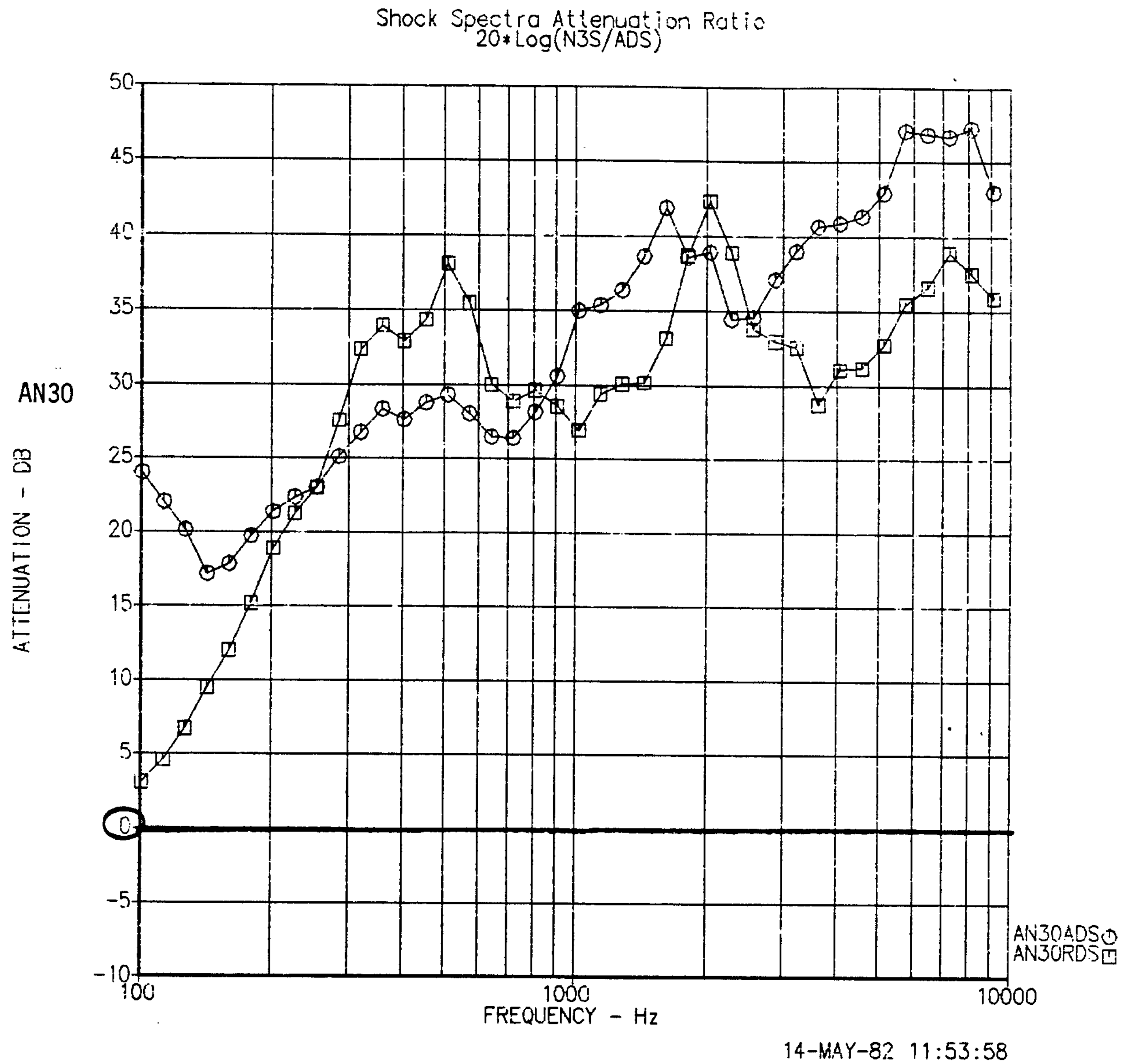
APPD.						

AN30* = AN30*DSP.DB = A1* + A5* + A6*

* = A or R



ATTENUATION AN30

SPACECRAFT ADAPTER AT 33°

TO POWER AMPLIFIER, N30, AT 351°, ISOLATED SIDE

○ Axial, AN30A

□ Radial, AN30R

CALC	OB	14MAY82	REVISED	DATE	
CHECK					FIGURE 3.3.5
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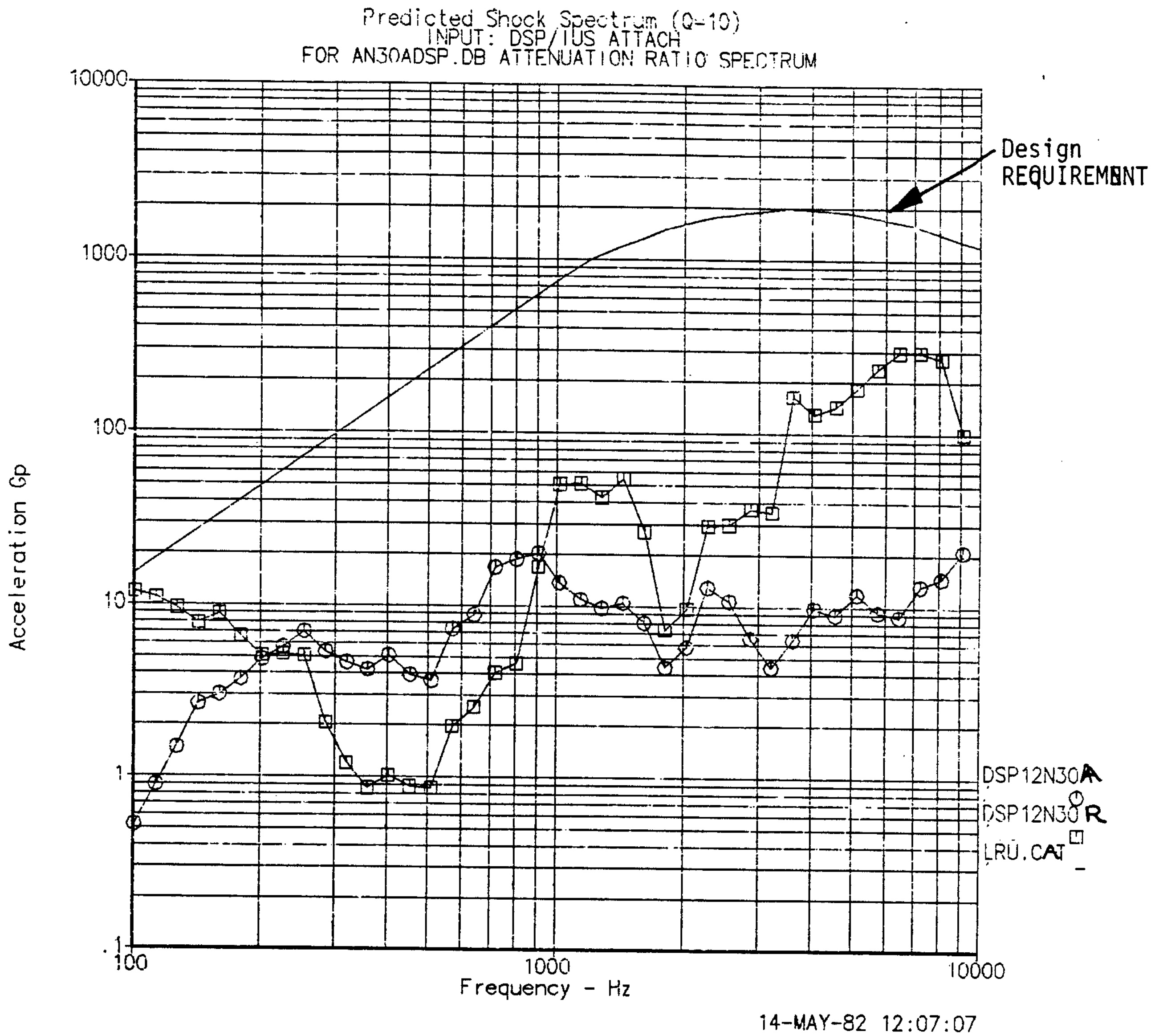
APPD.					THE BOEING COMPANY

$$DSP12N30*. = S_s(10^{-AN30*/20})$$

$* = A$ or R



DSP 12,13 INDUCED SHOCK

AT BASE OF POWER AMPLIFIER, ISOLATED SIDE

○ Axial
□ Radial

CALC	CB	14MAY82	REVISED	DATE	FIGURE 3.3.6	
CHECK						
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APPD.					THE BOEING COMPANY	PAGE D-42

3.4 Shock Prediction, SIU*, Transponder*, EMU* (Inner Conic)

The equations and data used to predict the SIU, Transponder and EMU shock response are shown on Figure 3.4.1. All of the equipment items are located on the inner conic structure at the locations shown in Figure 3.4.2. The predicted environments were calculated only for the SIU and Transponder A locations. The transponder is closer to the shock source than the other equipment items The predicted environments for the SIU and EMU will be less than the transponder environment. The SIU environment was calculated because it has a lower design requirement. The predicted environments are shown in Figures 3.4.6 and 3.4.7.

*SIU, BAC Drawing 290-26199/CI290199A
Transponder, BAC Drawing 290-22121/CI290018A
EMU, BAC Drawing 290-22224

GENERAL EQUATION SEE FIGURE 3.4.2

$$S_C = S_S\left(10^{-\frac{A1-A9-A10-AB}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, see Figs. 3.1.3

A9 = Attenuation between IUS Sep Nut and Inner Conic Structure.

A10 = Attenuation between top of ESS Longeron and IUS Sep Nuts, See Fig 3.5.3.

AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.4.3

$$A9 = 20 \log \frac{(\bar{S}_{I}d)_f}{(\bar{S}_{C}d)_f}$$

- Assumes S_I same at all longerons
- Shock path 40 in. average

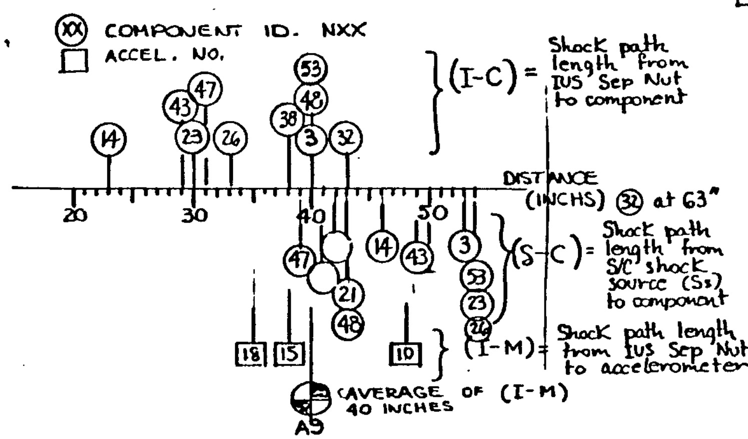
QTV ACCELS	
S_I	S_C
1 ART	10 ART
70 ART	15 ART
	18 ART

$$AB = 20 \log \frac{(I-C)}{40}$$

See Figures 3.4.4 and 3.4.5

$$AN14 = A1 + A9 + A10 - 4.8$$
$$AN47 = A1 + A9 + A10 - 2.2$$

COMPONENT	Inches I-C	db AB
N3	40	0
N14 XPONDER A	23	-4.8
N21	38	-0.5
N23 EMU	42	+0.4
N26 "	33	-1.7
N32 "	42	+0.4
N43	29	-2.8
N47 SIU	31	-2.2
N48	23	-4.8
N53 XPONDER B	40	0



FINAL EQUATIONS

$$S_{N14} = S_S\left(10^{-\frac{A1-A9-A10+4.8}{20}}\right)$$

$$S_{N23} = S_S\left(10^{-\frac{A1-A9-A10-0.4}{20}}\right)$$

$$S_{N47} = S_S\left(10^{-\frac{A1-A9-A10+2.2}{20}}\right)$$

Predicted shock spectra are shown on Figures 3.4.6 and 3.4.7

FIGURE 3.4.1
INNER CONIC EQUIPMENT
SHOCK EQUATIONS

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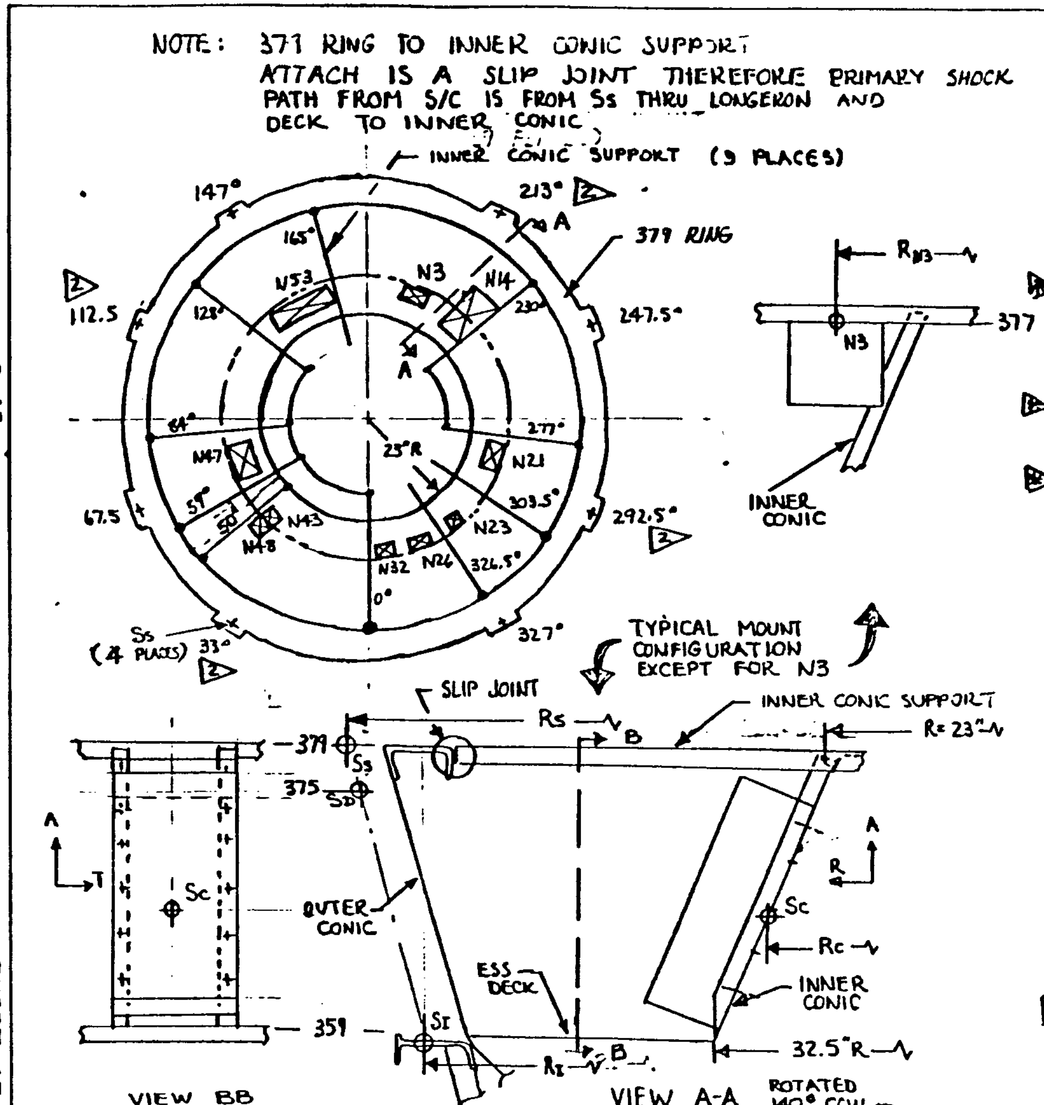


COMPONENT					SOURCE NEAREST COMPONENT						PATH LENGTH - INCHS ①	
ID	NAME	LOCATION			S_I - IUS			S_S - S/C				
		X_C	θ_C	R_C	X_I	θ_I	R_I	X_S	θ_S	R_S	I-C	S-C
N3	TVC B	377	203°	31"	359	213	51	379	213	56	40/4	53/4
N14	TRANSPONDER A	368	225°	28"		213			213		23/2	46/2
N21	TVC A	375	290°	24		292.5			292.5		38/3	43/3
N23	EMU	369	320.5°	30		327			292.5		30/3	54/4
③ N26	DECRYPTOR A	371.5	336°	30		327			292.5		33/3	54/4
N32	DECRYPTOR B	371.5	353°	30		327			292.5		42/3	63/4
N43	ENCRYPTOR A	370	46°	28		33			133		29/2	49/2
③ N47	SIU	371	71.5	27		67.5			33		31/2	39/2
N48	ENCRYPTOR B	365	46°	31		33			33		23/2	55/4 43/3
③ N53	TRANSPONDER B	374	146.5°	25		147			112.5		40/3	54/3

① I-C = Shortest path from SI to Sc / Number of joints
S-C = Shortest path from SS to Sc / Number of joints

Sc = Geometric Center of Component Mount Plane
So = Spacecraft Shock Defined
SI = IUS Shock Source
Ss = Spacecraft Shock Source
R = Radius θ = Azimuth X = Axial Station

③ QTV INSTRUMENTATION

ACCEL.	COMPONENT	X_M	θ_M	R_M	PATH I-M	LENGTH S-M
10ART	N53	377	131°	26	47/3	61/3
15ART	N47	375	63°	27	38/2	40/2
18ART	N26	375	330°	32	35/3	43/3

A = AXIAL
R = RADIAL
T = TANGENTIAL

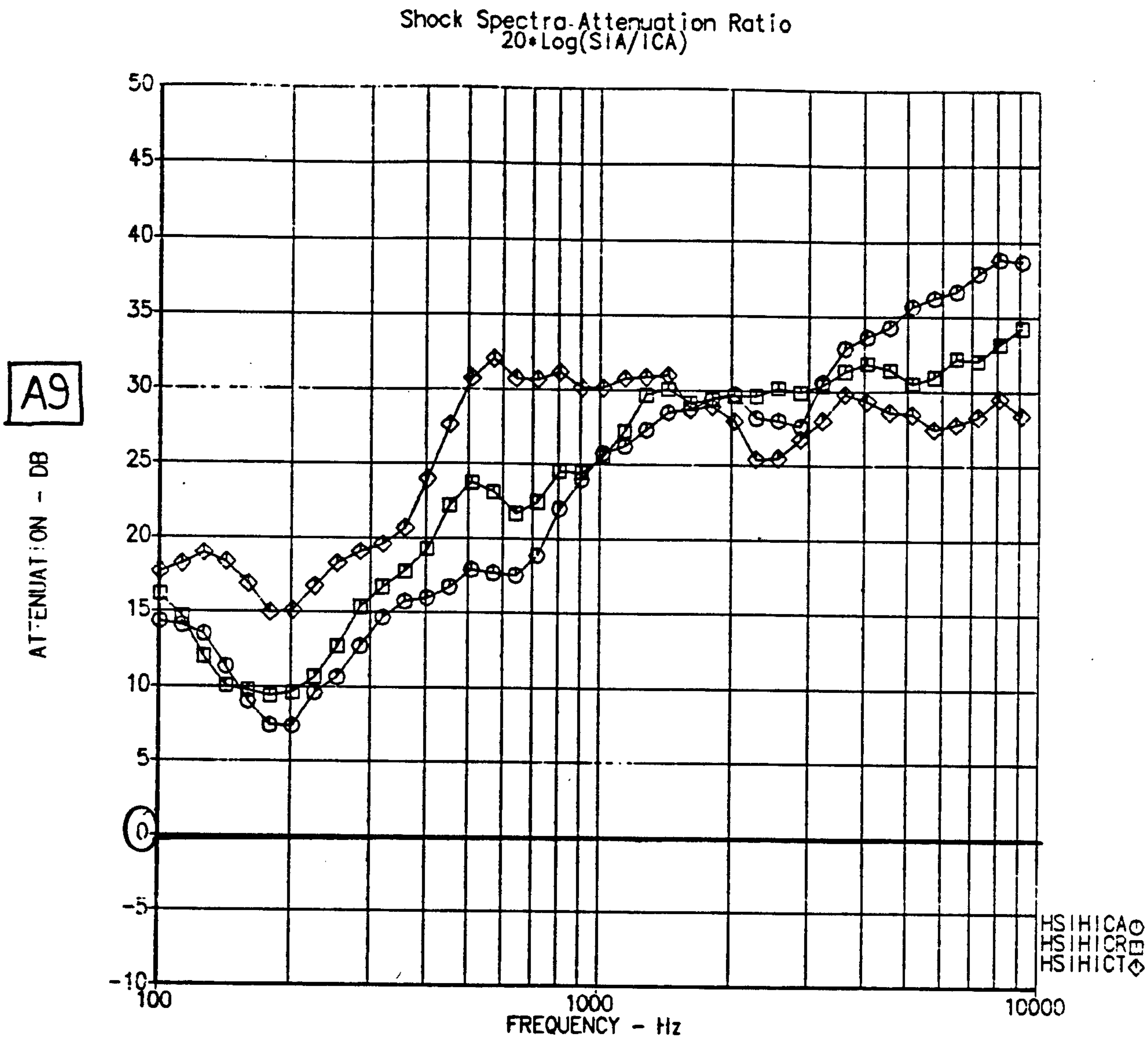
I-M = Shortest Path from SI to Measurement (M)/No. of joints
S-M = " " " Ss to M/No. of joints

② DSP attaches to IUS at θ = 33°, 112.5°, 213°, 292.5°

FIGURE 3.4.2
INNER CONIC SHOCK PATHS

O Attenuation A9A (Axial)
□ Attenuation A9R (Radial)
◇ Attenuation A9T (Tangential)
= HSIHIC*DB
* = A, R or

A9



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ATTENUATION A9
BETWEEN IUS SEP NUT AND INNER CONIC

Axial
Radial
Tangential

CALC	C/B	23APR82	REVISED	DATE	FIGURE 3.4.3	
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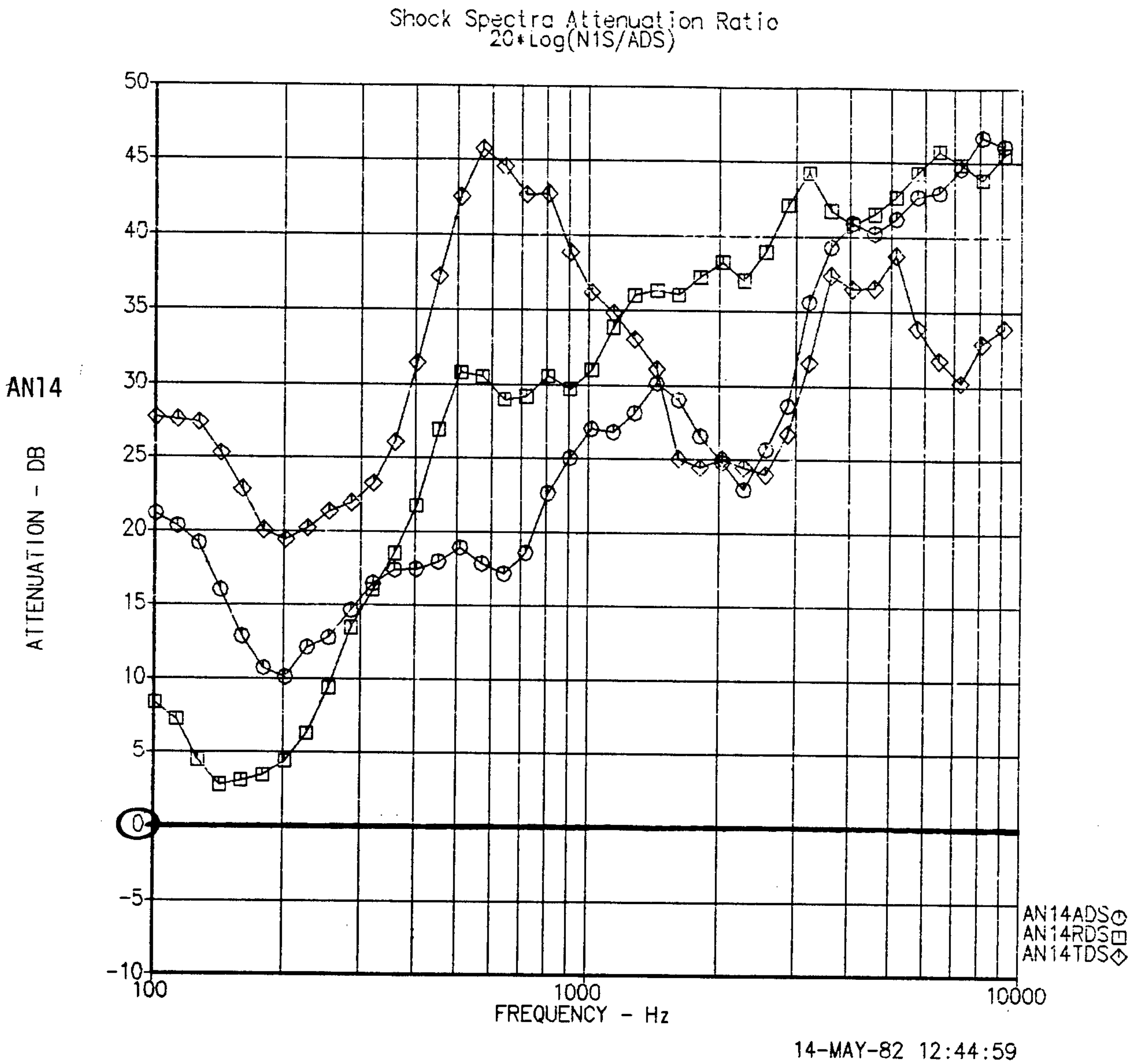
A

AN14* = AN14*DSP.DB = A1* + A9* + A10* -4.8

* = A,R or T



ATTENUATION AN14

SPACECRAFT ADAPTER AT 213°

TO TRANSPONDER A, N14, AT 225°

○ Axial, AN14A
□ Radial, AN14R
◇ TAngential, AN14T

CALC	CB	14MAY82	REVISED	DATE	FIGURE 3.4.4	
CHECK						
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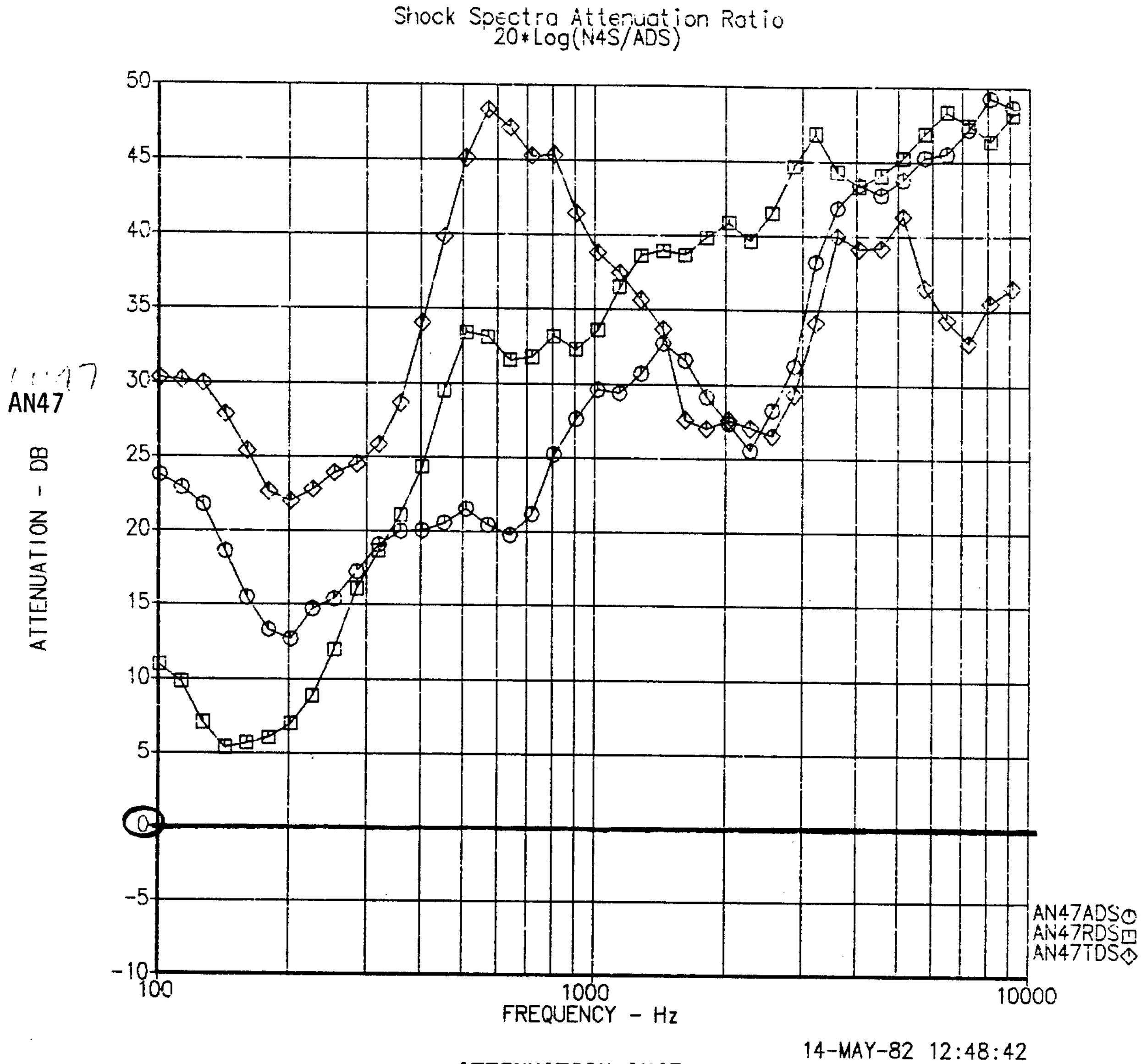
AN47* = AN47*DSP.DB = A1* + A9* + A10* -2.2

* = A,R or T



ATTENUATION AN47

SPACECRAFT ADAPTER AT 33°

TO SIU, N47, AT 71.5°

○ Axial, AN47A
□ Radial, AN47R
◇ Tangential, AN47T

CALC		14MAY82	REVISED	DATE	FIGURE 3.4.5
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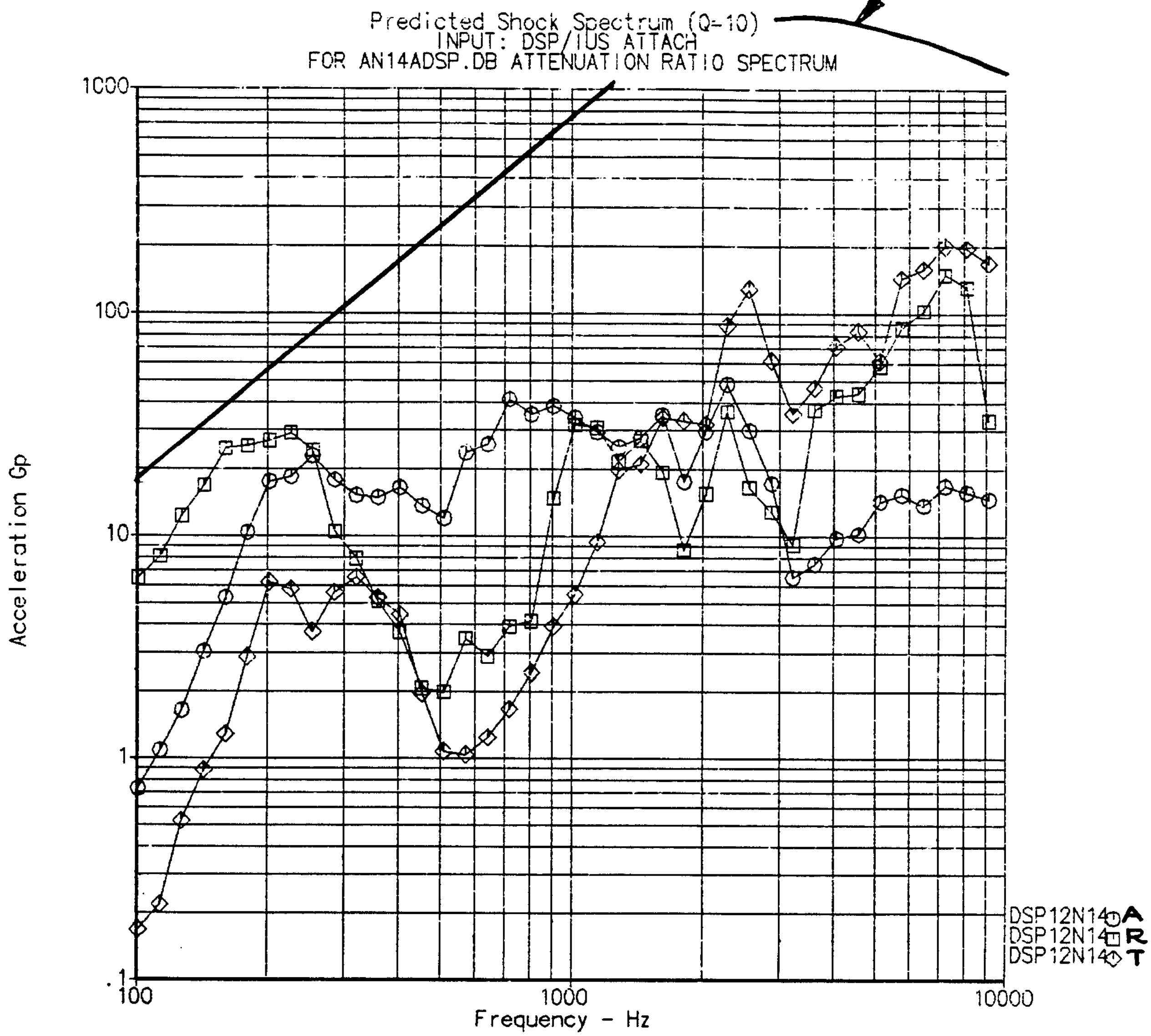
DSP12N14*. = S_s $(10^{-AN14*/20})$

* = A,R or T

Design Requirement



DSP 12,13 INDUCED SHOCK

AT TRANSPONDER A, LOCATION N14

O Axial
□ Radial
◇ Tangential

CALC	CB	14MAY82	REVISED	DATE	FIGURE 3.4.6	
CHECK						
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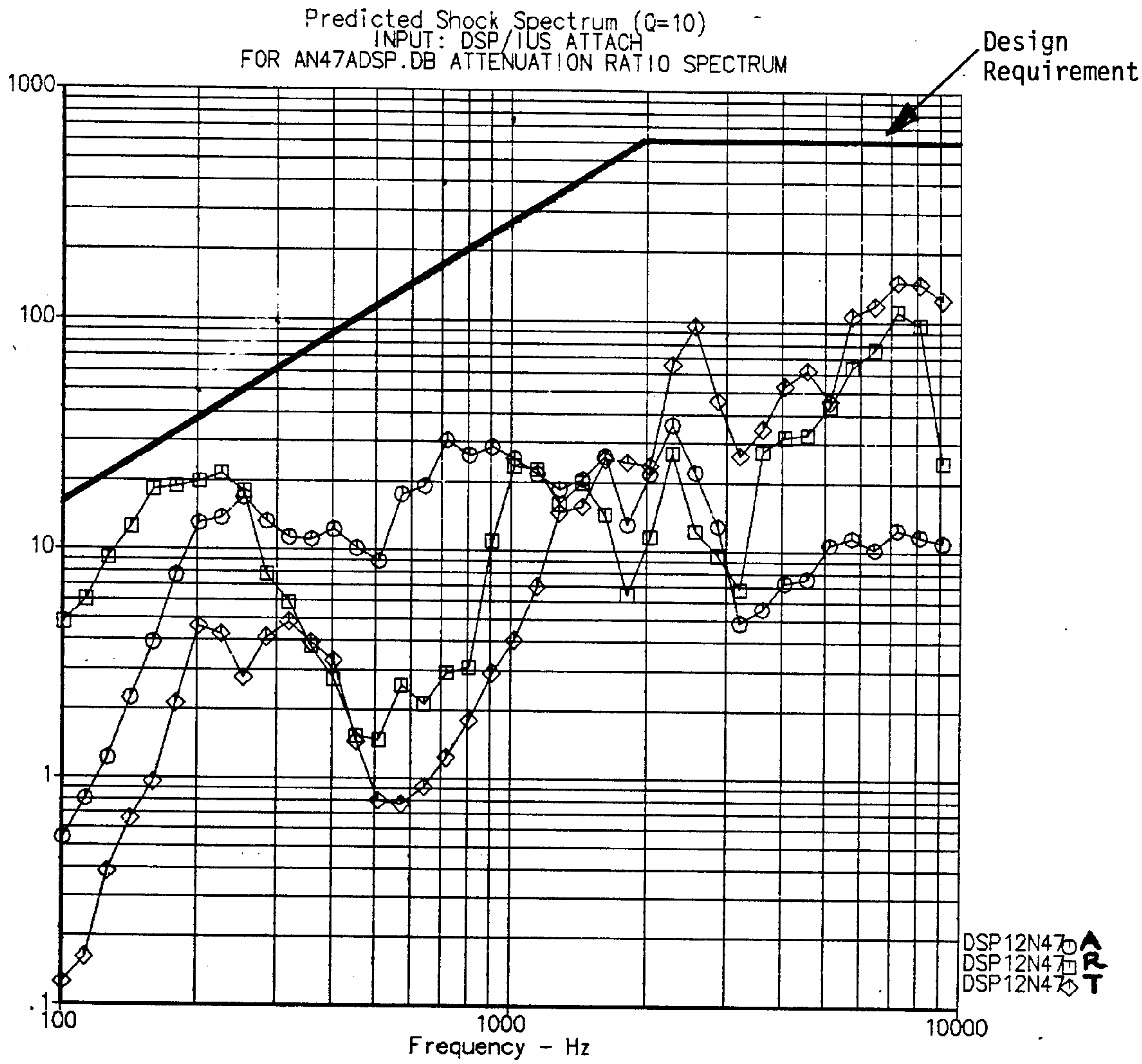
$$DSP12N47*. = S_s (10^{-AN47*/20})$$

$* = A,R \text{ or } T$



DSP 12,13 INDUCED SHOCK
AT SIU LOCATION , N47

○ Axial
□ RAdial
◇ Tangential

CALC	qs	14MAY82	REVISED	DATE	FIGURE 3.4.7	
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APPD.					THE BOEING COMPANY	PAGE D-50

3.5 ESS Batteries* Shock Prediction

The equations and data used to predict the shock environment on the ESS batteries are shown on Figure 3.5.1. The battery locations are shown on Figure 3.5.2. The predicted environments for the batteries closest to the shock source are shown in Figure 3.5.6.

*BAC Drawing 290-22212

BOEING

NUMBER
REV LTR

GENERAL EQUATION   SEE FIGURE 3.5.2

$$S_C = S_S\left(10^{-\frac{A1-A10-A11-AB}{20}}\right)$$

A1 = Attenuation across IUS/spacecraft joint, see Figs 3.1.3
A10 = Attenuation between top of ESS Longeron and IUS Sep Nut
A11 = Attenuation between IUS Sep Nut and Battery attach point.
AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)
S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
S_S = Spacecraft Shock Source located at the Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels
$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)
f = 1/6 octave band center frequencies

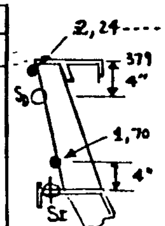
APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.5.3

$$A10 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{Ld})_f}$$

- Assumes S_I same for all longerons
- Shock path = 16 in.

QTV ACCELS	
S_I	S_L
1 ART	2ART
70ART	24 AR
	25 ART
	37 ART
	-
	39 A



See Figure 3.5.4

$$A11 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{cd})_f}$$

- Assumes S_I same for all longerons
- Shock path = 21 in.

QTV ACCELS	
S_I	S_C
1 RT	7 RT
70 RT	

$$AB = 20 \log \frac{(I-C)}{21}$$

See Figure 3.5.5

$$AN04 = A1 + A10 + A11 - 3.5$$

ID.	I-C (INCHES)	AB (DB)
N4	14	-3.5
N5	20	-0.4
N6	26	+1.9
N9	14	-3.5
N10	20	-0.4
N11	26	+1.9

I-C = Shock path from IUS Sep Nut to Battery Attach point.

FINAL EQUATIONS

$$S_{N4} = S_{N9} = S_S\left(10^{-\frac{A1-A10-A11+3.5}{20}}\right)$$
$$S_{N5} = S_{N10} = S_S\left(10^{-\frac{A1-A10-A11+0.4}{20}}\right)$$
$$S_{N6} = S_{N11} = S_S\left(10^{-\frac{A1-A10-A11-1.9}{20}}\right)$$

⇐ Predicted shock spectra shown on Figure 3.5.6

FIGURE 3.5.1
ESS BATTERIES
SHOCK EQUATIONS

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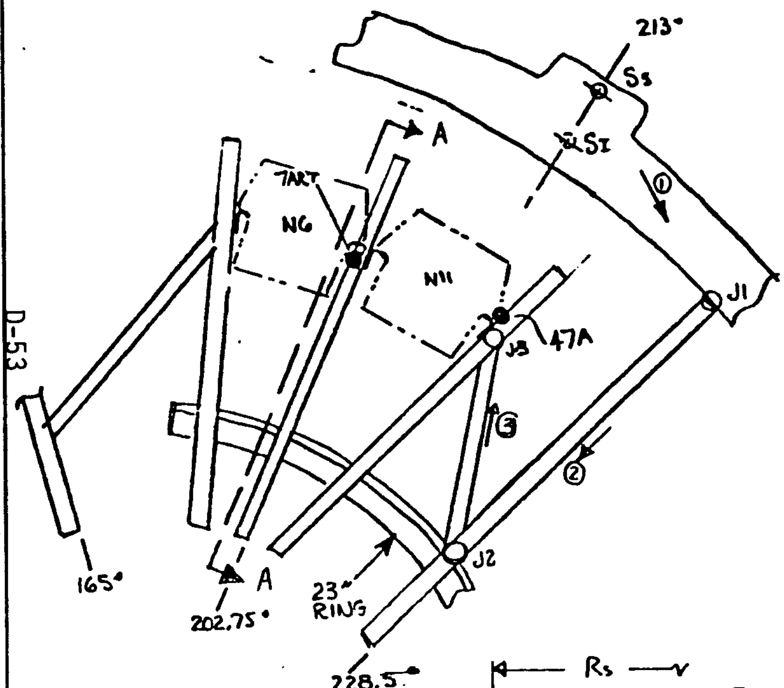
BOEING

NUMBER
REV LTR



SHOCK PATH CALCULATIONS

IUS SOURCE (SI) TO NEAREST BATTERY (I-C)

① From 213° Nut (SI) thru Joint 1 across deck to Battery Support 13"

② Thru Joint 2 up Battery Support to first Battery Attach Point (N9) 1"

I-C = TOTAL 14" 2 JOINTS

Spacecraft source (Ss) to nearest battery via Inner Conic support structure (S-C)₁

① From 213° Spacecraft Attach Point (Ss) to Inner Conic Support @ 228.5° 17"

② Thru Joint 1 along support to 23" Ring 25"

③ Thru Joint 2 along Brace to Battery Support 15"

④ Thru Joint 3 along Battery Support to first Battery Attach Point (N11) 1"

$(S-C)_1$ = ~~TOTAL 58" 3 JOINTS~~

Spacecraft source (Ss) to battery via Longeron $(S-C)_2$

① From 213° Ss thru longeron/ring joint to longeron, along longeron to 359 joint 20"

② Across deck, up support to Battery N9 14"

$(S-C)_2$ = TOTAL 34" 3 JOINTS

QTV INSTRUMENTATION		
NO.	I-M	D-M
7ART	21"/2	37"/2
47A	14"/2	30"/2

I-M = Shortest Path from SI to Accel. (M)/No. of joints.

D-M = Shortest Path SD to M/joints.

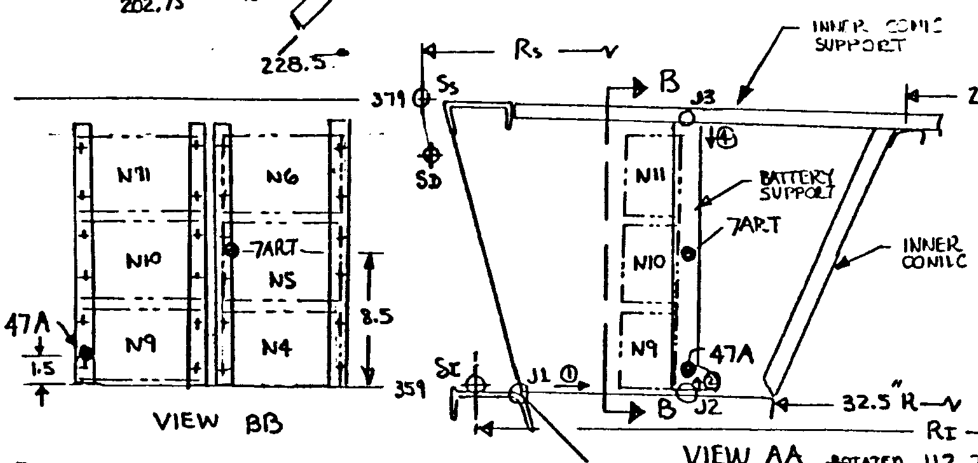
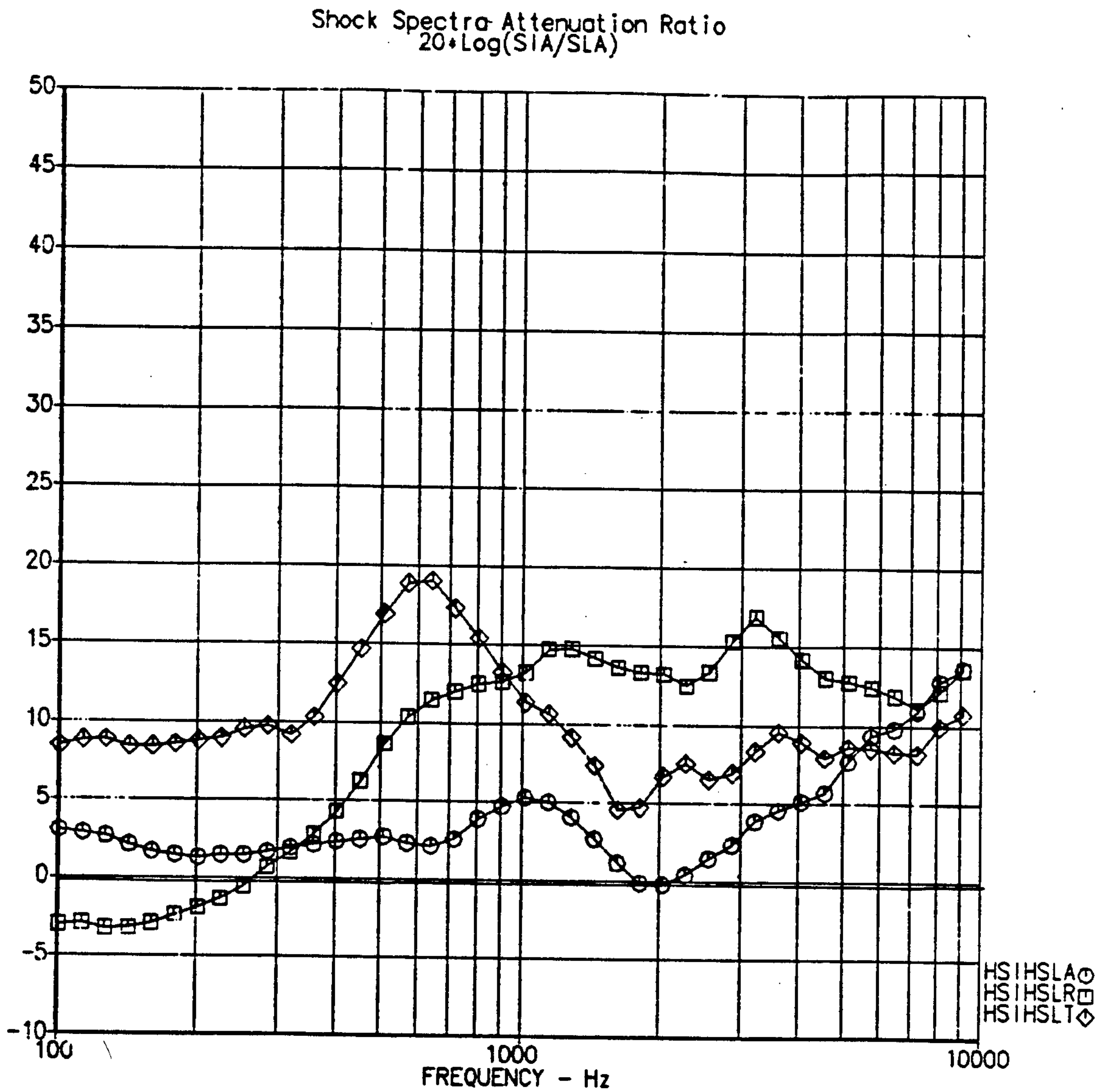


FIGURE 3.5.2
ESS BATTERIES
SHOCK PATHS

CJB 4/26/82

○ Attenuation A10A (Axial) = HSIHSLA.DB
□ Attenuation A10R (Radial) = HSIHSLR.DB
◇ Attenuation A10T (Tangential) = HSIHSLT.!

A10



23-APR-82 12:15:44

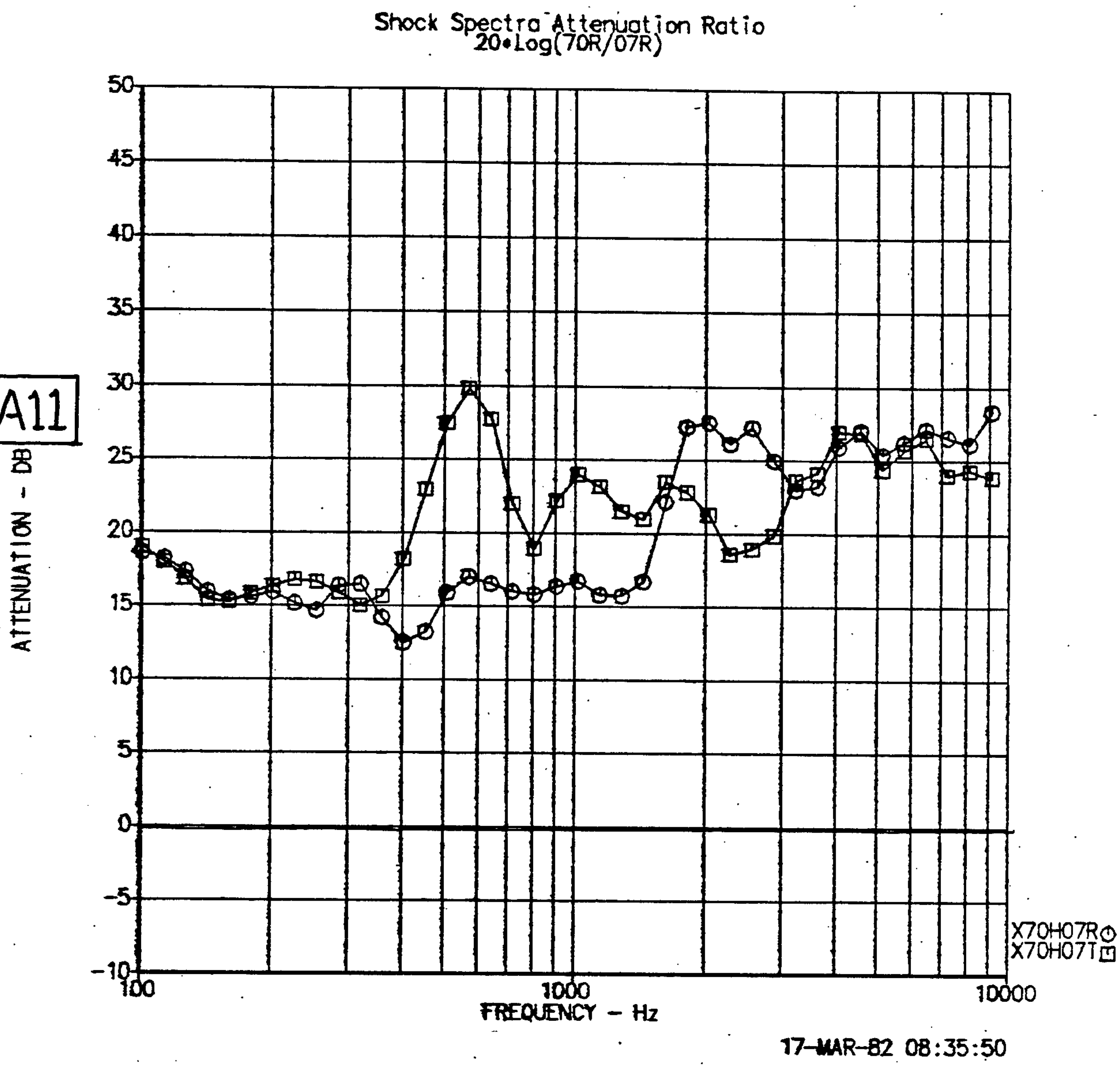
ATTENUATION A10
BETWEEN TOP OF ESS LONGERON
AND IUS SEP NUT

AXIAL
RADIAL
TANGENTIAL

CALC	CB	23APR82	REVISED	DATE	FIGURE 3.5.3	
CHECK						
APPD.					THE BOEING COMPANY	PAGE D-54
APPD.						

○ A11R (Radial) = X70H07R.DB
□ A11 T (Tangential) = X70H07T.DB

A11



ATTENUATION A11
BETWEEN IUS SEP NUT AND BATTERY

CALC	CB	17MAR82	REVISED	DATE	FIGURE 3.5.4	
CHECK						
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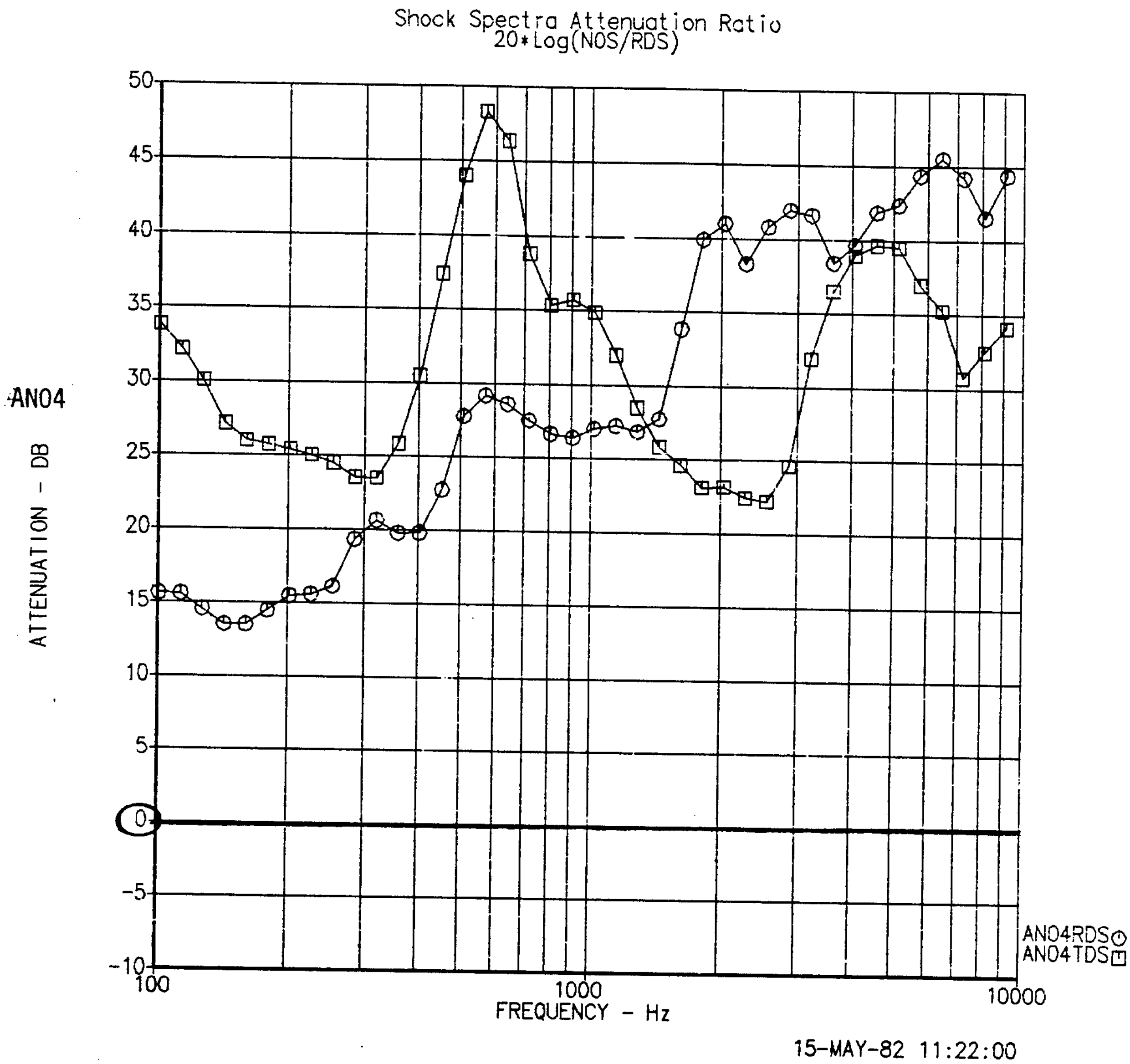
APPD.					THE BOEING COMPANY	PAGE D-55

AN04* = NA04*DSP.DB = A1* + A10* + A11* - 3.5

* = R or T



ATTENUATION AN04

SPACECRAFT ADAPTER AT 213°

TO BATTERY, N4

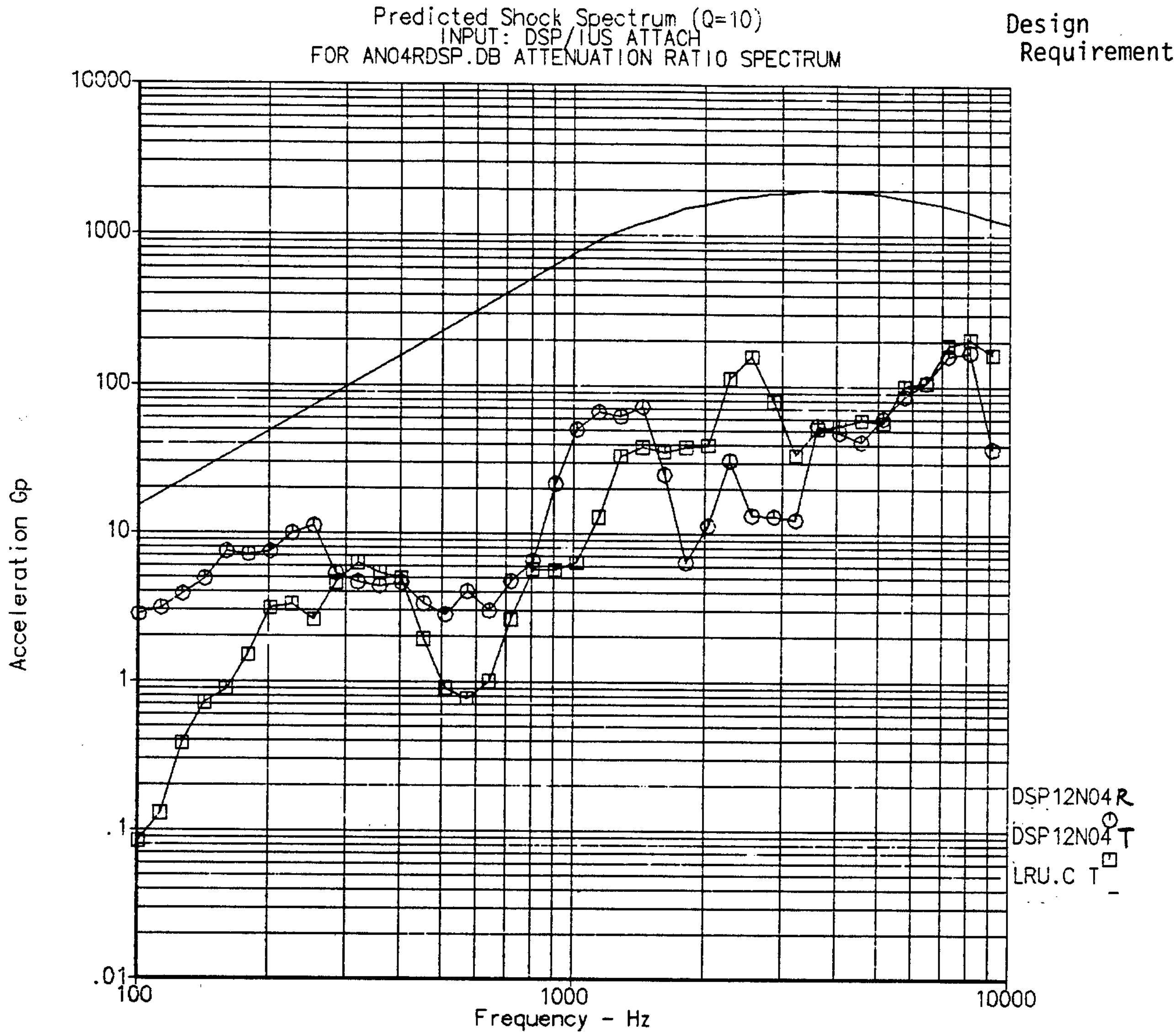
O Radial, AN04R

☐ TAngential, AN04T

CALC	~~DB~~	15MAY82	REVISED	DATE		
CHECK					FIGURE 3.5.5.	
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-56

$$DSP12N04*. = S_s (10^{-AN04*/20})$$

$* =$ R or T



DSP 12,13 INDUCED SHOCK

AT ESS BATTERY LOCATION, N4

O Radial

□ TAngential

CALC		15MAY82	REVISED	DATE	FIGURE 3.5.6	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-57

3.6 Shock Prediction. RCS*, IMU*, SCU*, PDU* (ESS Deck)

The equations and data used to predict the shock environments for equipment mounted on the ESS deck are shown on Figure 3.6.1. The locations of the equipment are shown on Figure 3.6.2. Figures 3.6.8 through 3.6.10 contain predicted shock spectra for the PDU, RCS and SCU. The IMU prediction is not shown since it is similar but less than the RCS prediction.

*RCS Manifold, BAC Drawing 290-21031
RCS Tank, BAC Drawing 290-21007
RCS Resistor Board, BAC Drawing 290-21066
IMU, BAC Drawing 290-22118
SCU, BAC Drawing 290-26016
PDU, BAC Drawing 290-26117

GENERAL EQUATION SEE FIGURE 3.6.2

$$S_c = S_s\left(10^{\frac{-A1-A10-A12-A13-AB}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, Figs 3.1.3
A10 = Attenuation between top of ESS Longeron and IUS Sep Nut, Fig. 3.5.3
A12 = Attenuation between IUS Sep Nut and ESS deck.
A13 = Attenuation across PDU isolator.
AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

- S_C = Shock level on Component. (Calculated)
- S_{NX} = Shock level on Specific Component, NX (Calculated)
- S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).
- S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts
- S_S = Spacecraft Shock Source located at the Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.
- A = Calculated Attenuation in decibels
- $\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

- d = Shock direction (A = Axial, R = Radial, T = Tangential)
- f = 1/6 octave band center frequencies

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Fig. 3.6.3

$$A12 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{Cd})_f}$$

- Assumes S_I same at all longerons
- Shock path 16 in average

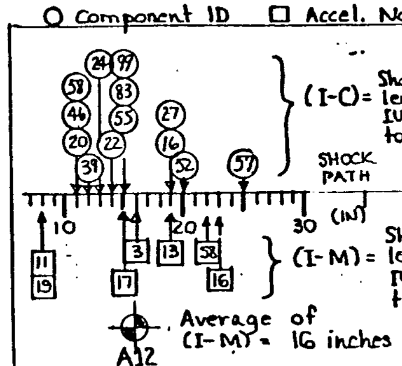
QTV ACCELS	
S_I	S_C
1 ART 70 ART	3 ART 11 ART 13 AR 16 ART 17 ART 19 ART 58 R

See Fig. 3.6.4

$$A13 = 20 \log \frac{(\bar{S}_{CIN d})_f}{(\bar{S}_{COUT d})_f}$$

QTV ACCELS	
S_{CIN}	S_{COUT}
13 AR	12 AR

○ Component ID □ Accel. No.



See Figures 3.6.5 thru 3.6.7

AN20 = A1 + A10 + A12 + A13 − 3.2
AN39 = A1 + A10 + A12 − 2.5
AN46 = A1 + A10 + A12 + 6.6

$$AB = 20 \log \frac{(I-C)}{16}$$

	ID.	INCHES I-C	db AB
RCS	N16	19	+1.5
PDU	N20	11	−3.2
PDU	N22	14	−1.2
	N24	13	−1.8
	N27	19	+1.5
RCS	N39	12	−2.5
SCU	N46	34	+6.6
RCS	N52	20	+1.9
	N55	15	−0.6
	N58	11	−3.2
IMU	N59	25	+3.9
	N83	15	−0.6
	N99	15	−0.6

FINAL EQUATIONS

$$S_{N20} = S_s\left(10^{\frac{-A1-A10-A12-A13+3.2}{20}}\right)$$
$$S_{N39} = S_s\left(10^{\frac{-A1-A10-A12+2.5}{20}}\right)$$
$$S_{N46} = S_s\left(10^{\frac{-A1-A10-A12+6.6}{20}}\right)$$

Predicted shock spectra shown on Figures 3.6.8 thru 3.6.10

FIGURE 3.6.1
ESS DECK EQUIPMENT
SHOCK EQUATIONS

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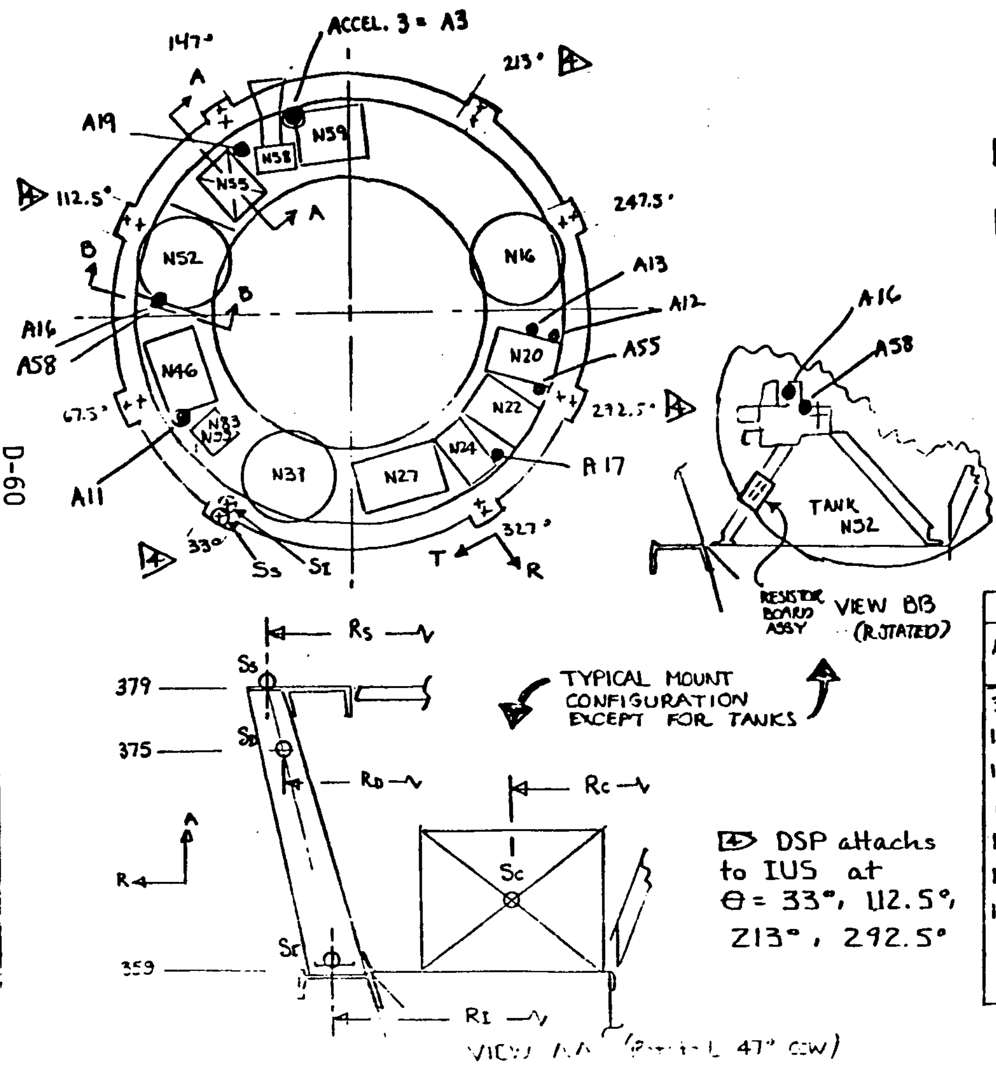
NUMBER
REV LTR



▷ DSP attachs to IUS at θ = 33°, 112.5°, 213°, 292.5°

COMPONENT					SOURCE NEAREST COMPONENT						PATH LENGTH/NUMBER OF JOINTS ▷	
		LOCATION			SI – IUS			SD – S/C				
ID.	NAME	Xc	θc	Rc	XI	θI	RI	XD	θD	RD	I-C	D-C
N16	RCS TANK 3	368	253°	40	359	247.5	51	375	292.5	55	13/2	52/2
▷ N20	PDU(A)	359	285	42		292.5			292.5		11/1	27/1
N22	PDU(B)	359	304	42		292.5			292.5		14/1	30/1
▷ N24	PTU	359	320.5	40		327			292.5		13/1	44/1
N27	SCU (A)	359	344	39		327			33		19/1	58/1
N37	RCS TANK 2	368	23.5	40		33			33		12/2	28/2
▷ N46	SCU (B)	359	71.5	42		67.5			112.5		11/1	50/1
▷ N52	RCS TANK 1	368	107	40		112.5			112.5		20/2	36/2
▷ N55	PSU	359	137	40		147			112.5		15/1	42/1
N58	STAR SCANNER		157	44		147			112.5		11/1	55/1
▷ N59	RIMU		174	40		147			213		25/1	51/1
N83	TIU		45	42		33			33		15/1	31/1
N99	BATTERY		45	42		33			33		15/1	31/1

▷ QTV INSTRUMENTATION					▷	
					PATH LENGTH	
ACCEL	ID.	X_M	θ_M	R_M	I-M	D-M
3ART	N59	359	165	47	16/1	32/1
11ART	N46	360	61	48	8/2	24/2
12ART	▷N20'	360	277	46	18/2 ▷	34/2 ▷
13AR	N20	359	277	41	19/1	35/1
16ART	N52	371	90	44	23/4	39/4
17ART	N24	360	315	47	15/2	31/2
19ART	N55	360	143	44	8/2	24/2
55AR	▷N20'	360	293	48	10/2 ▷	26/2 ▷
58R	N52	370	92	42	22/3	38/3

A = Axial R = Radial T = Tangential

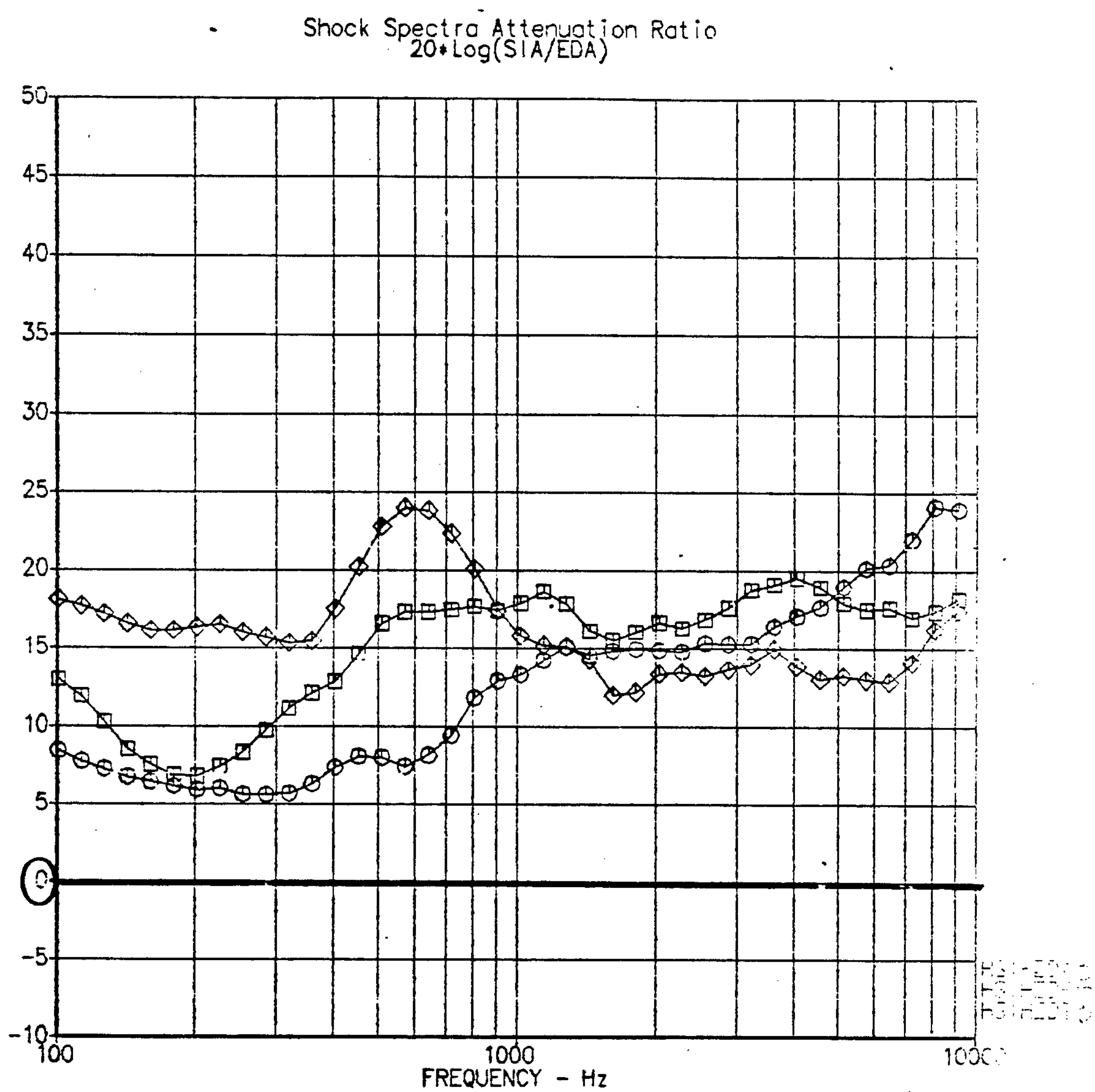
▷ Instrumentation on QTV
▷ On Component side of Isolators
▷ Shortest structural path from shock source to geometric center of component mount plane and number of joints in path
I-C Path from IUS Sep. Nut to component
D-C Path from S/C shock definition point to component
▷ Shortest structural path from shock source to acceleration measurement location and number of joints in path
I-M Path from IUS Sep. Nut to Accel.
D-M Path from S/C Shock definition point to Accel.

FIGURE 3.6.2
ESS DECK COMPONENTS
SHOCK PATHS

5/26/82

○ A12A (Axial) = HSIHEDA.DB
□ A12R (Radial) = HSIHEDR.DB
◇ A12T (Tangential) = HSIHEDT.DB

A12



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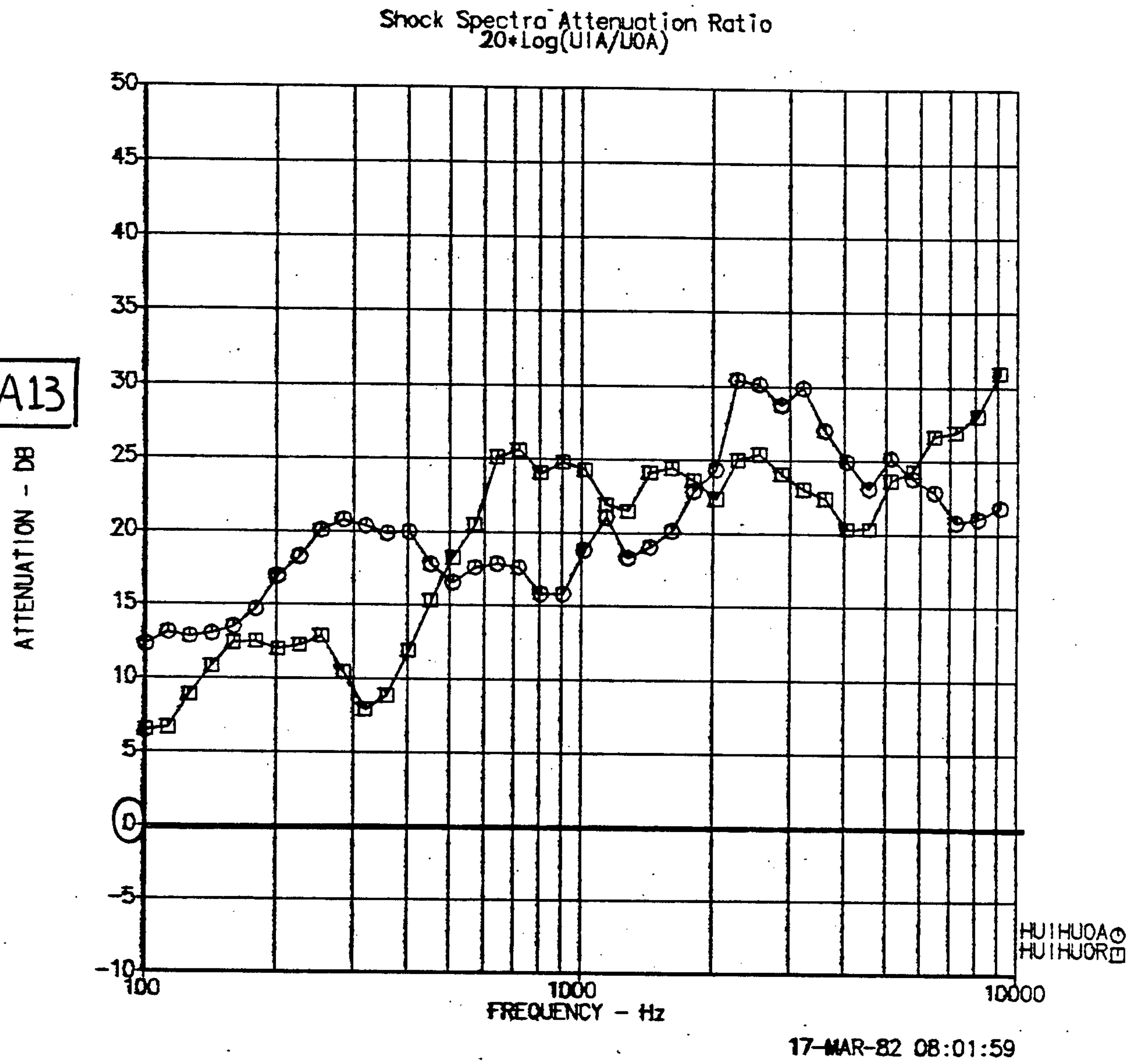
ATTENUATION A12
BETWEEN IUS SEP NUT AND ESS DECK

AXIAL
RADIAL
TANGENTIAL

CALC		9MAR82	REVISED	DATE	FIGURE 3.6.3	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-61

○ A13A (Axial) = HUIHUOA.DB
□ A13R (Radial) = HUIHUOR.DB



ATTENUATION A13
ACROSS PDU ISOLATOR

CALC		17MAR82	REVISED	DATE	FIGURE 3.6.4
CHECK					
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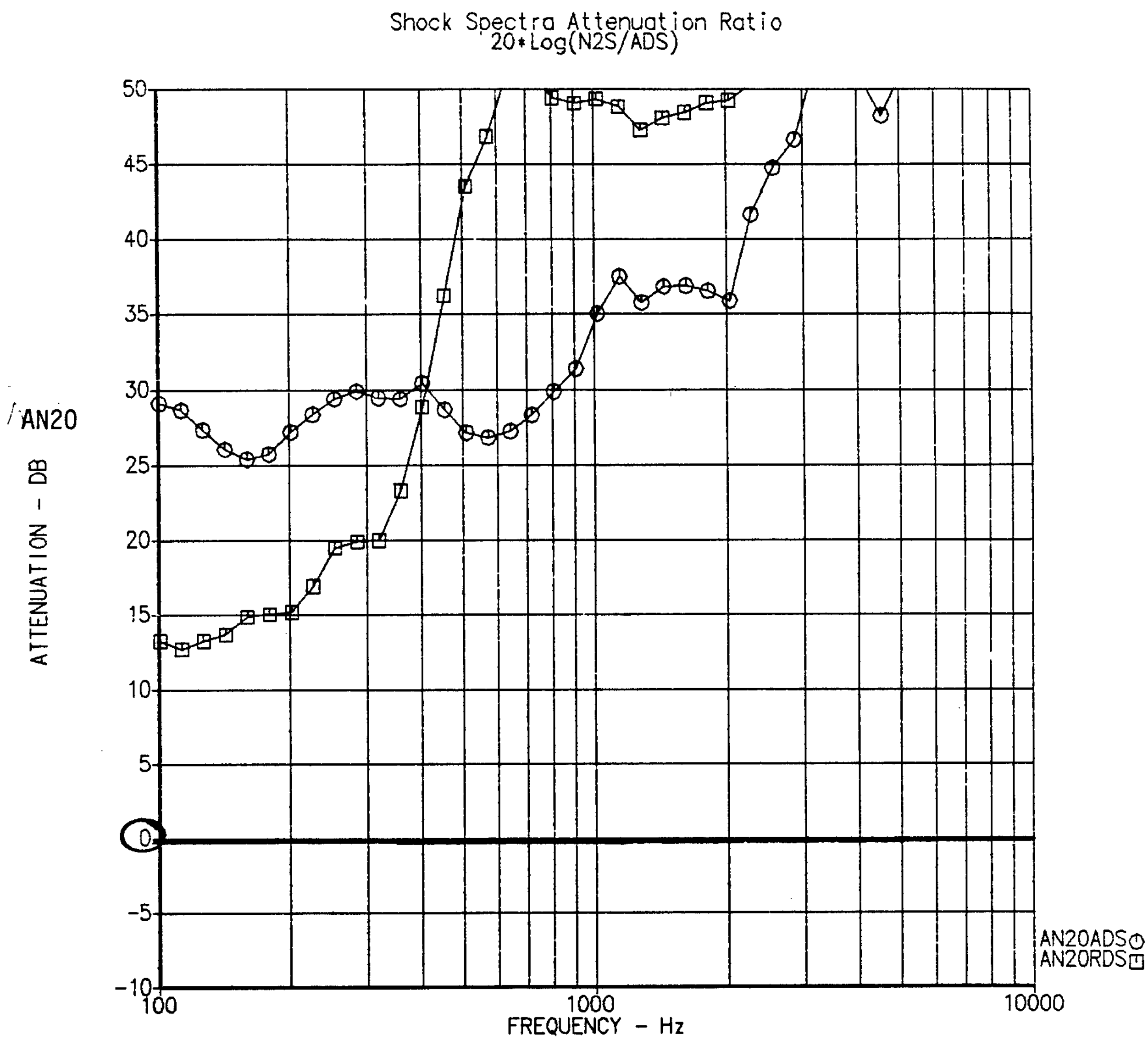
APPD.					THE BOEING COMPANY — PAGE D-62

AN20* = AN20*DSP.DB = A1* + A10* + A12* A13* - 3.2

* = A or R



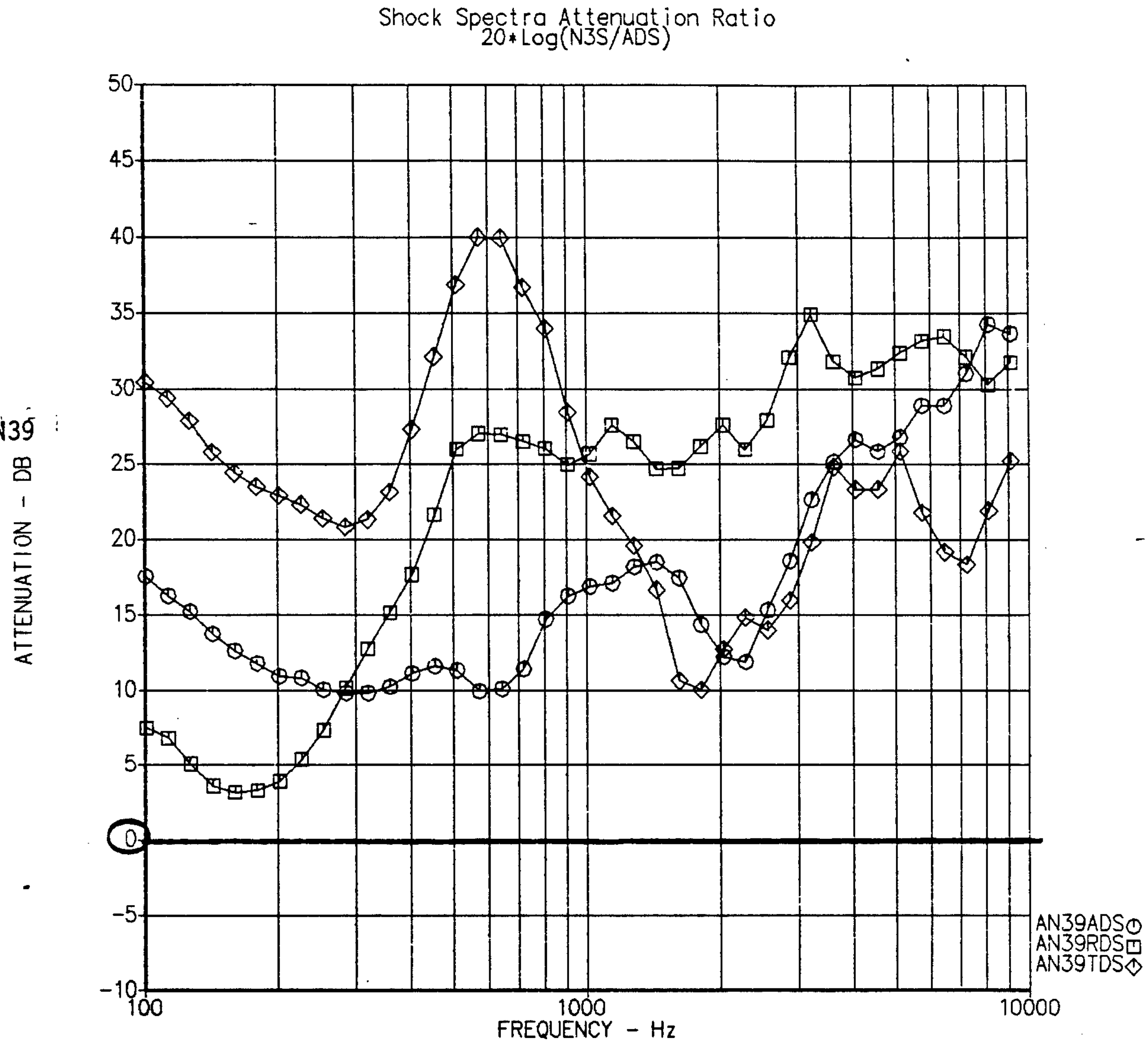
ATTENUATION A 20
SPACECRAFT ADAPTER AT 292.5°
TO PDU, N20, AT 285° (ISOLATED SIDE)

○ Axial, AN20A
□ Radial, AN20R

CALC	OJS	15MAY82	REVISED	DATE	FIGURE 3.6.5	
CHECK						
APPD.					THE BOEING COMPANY	PAGE D-63
APPD.						

AN39* = AN39*DSP.DB = A1* + A10* + A12* - 2.5

* = A or R or T



ATTENUATION AN39
SPACECRAFT ADAPTER AT 33°
TO RCS TANK, N39, AT 23.5°

O Axial A39A
□ RAdial, A39R
◇ Tangential, A39T

CALC	GB	15MAY82	REVISED	DATE	FIGURE 3.6.6	
CHECK						
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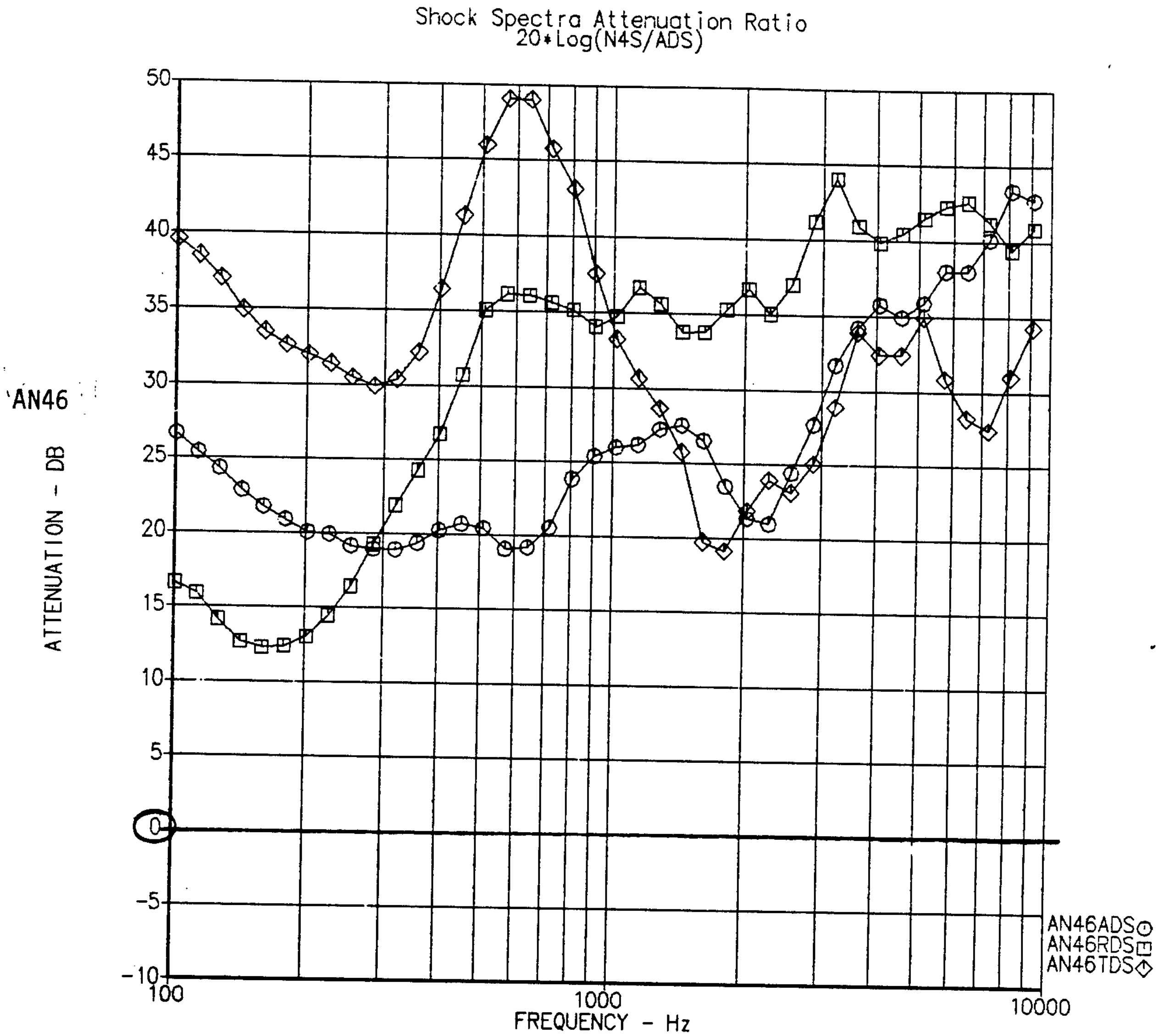
APPD.					THE BOEING COMPANY	PAGE D-64

AN46* = AN46*DSP.DB = A1* + A10* A12* + 6.6

* + A,R, or T



ATTENUATION AN46

SPACECRAFT ADAPTER AT 112.5°

TO SCU B, N46, AT 71.5°

○ Axial, A46A
□ Radial, A46R
◇ Tangential, A46T

CALC	QB	15MAY82	REVISED	DATE	FIGURE 3.6.7	
CHECK						
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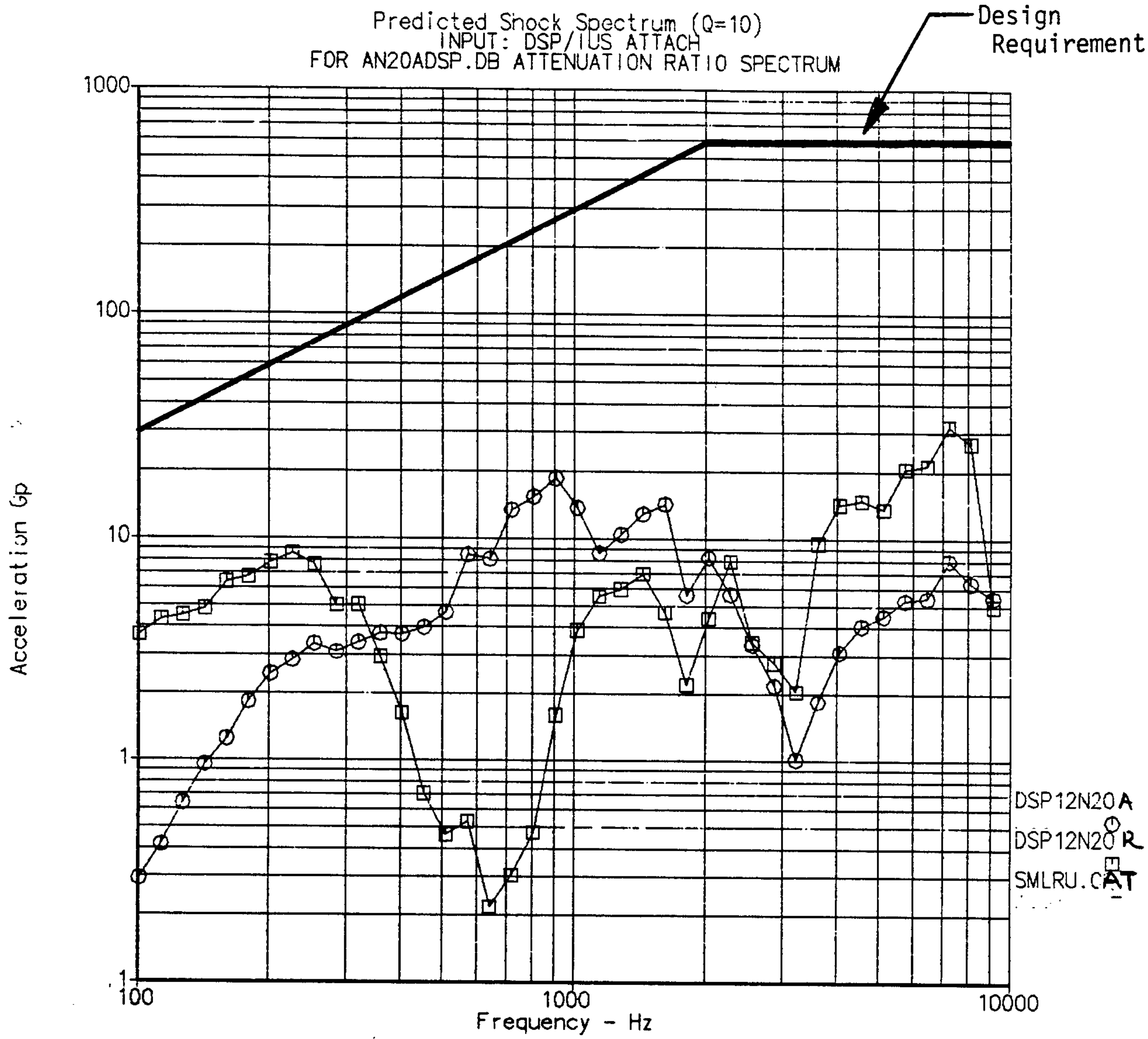
APPD.					THE BOEING COMPANY	PAGE D-65

$$DSPN20*. = S_s\ (10^{-AN20*/20})$$

$* =$ A or R



DSP 12,13 INDUCED SHOCK

AT PDU LOCATION, N20, (ISOLATED SIDE)

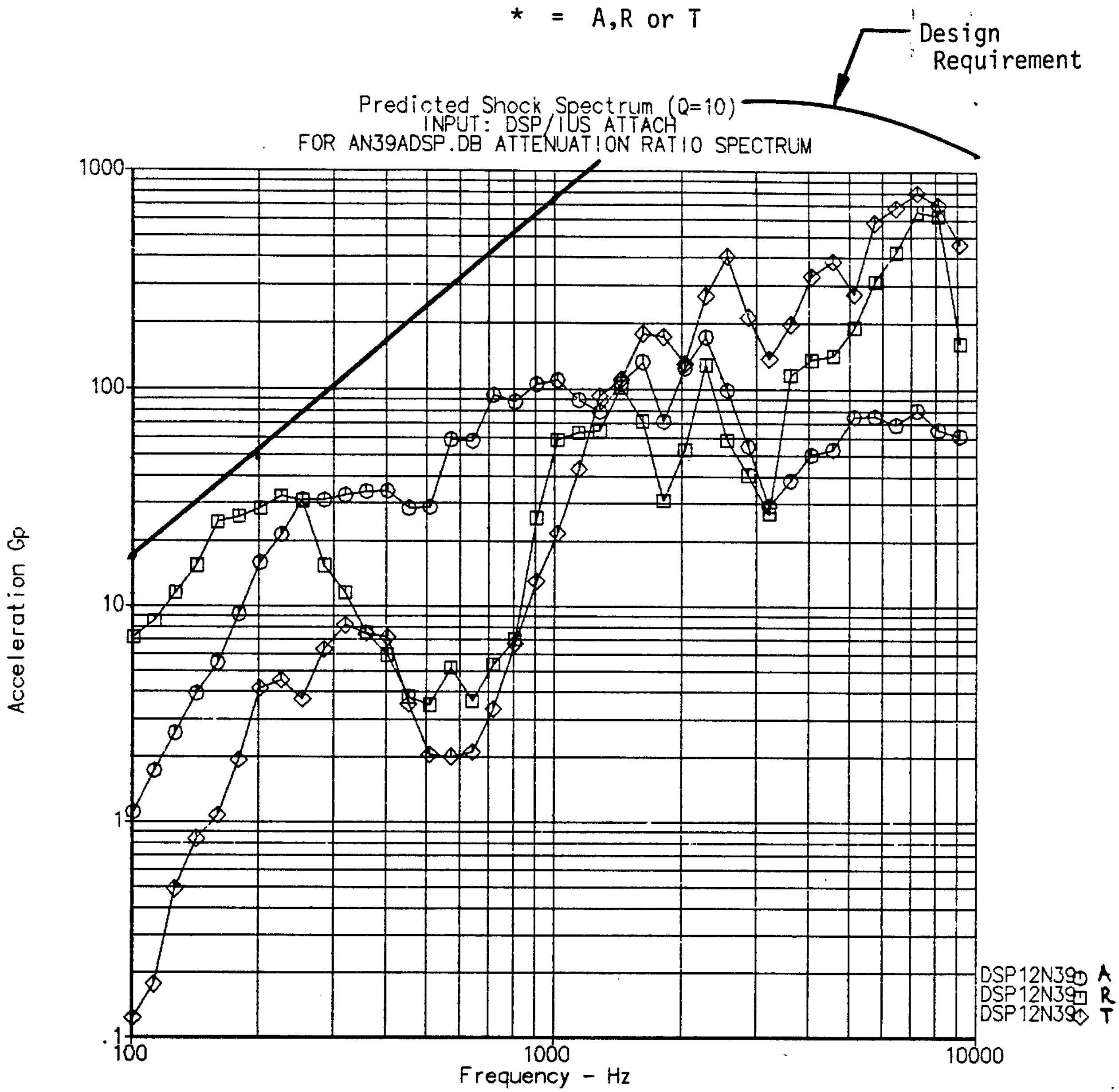
O Axial

□ Radial

CALC	CB	15MAY82	REVISED	DATE	FIGURE 3.6.8
CHECK					
APPD.					THE BOEING COMPANY
APPD.					PAGE D-66

$$DSP12N39*. = S_s\ (10^{-AN39*/20})$$

$* = $ A,R or T



DSP12,13 INDUCED SHOCK

AT RCS TANK LOCATION, N39

O Axial

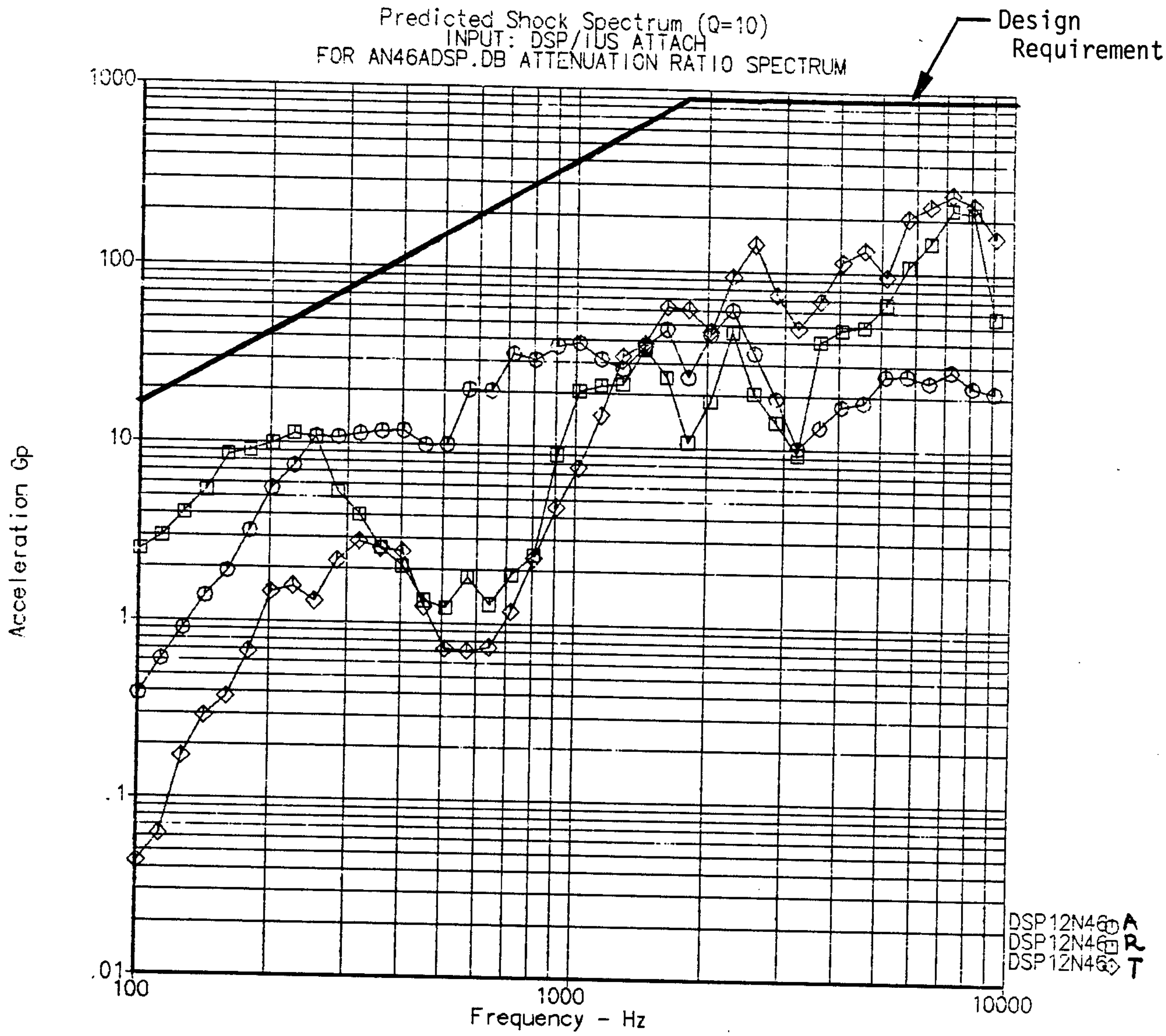
□ Radial

◇ Tangential

CALC	0/3	15MAY82	REVISED	DATE	FIGURE 3.6.9	
CHECK						
APPD.					THE BOEING COMPANY	PAGE D-67
APPD.						

$$DSP12N46^*. = S_s (10^{-AN46^*/20})$$

$$^* = A,R \text{ or } T$$



DSP 12,13 INDUCED SHOCK 20-MAY-82 07:31:15

AT SCU B LOCATION, N46

O Axial

□ Radial

◇ Tangential

CALC	OB	20MAY82	REVISED	DATE	FIGURE 3.6.10	
CHECK						
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APPD.					THE BOEING COMPANY	PAGE D-68

3.7 Shock Prediction, RF Switch*, Fail Safe RF Relay*, Diplexer*

The equations and data used to predict the shock spectra for the RF Switch, RF Relay and Diplexer are shown on Figure 3.7.1. Equipment locations are shown on Figure 3.7.2. The predicted spectra are shown in Figures 3.7.6 through 3.7.11.

*RF Switch, BAC Drawing 280-41008
Fail Safe RF Relay, BAC Drawing 280-41009
Diplexer, BAC Drawing 290-22200

GENERAL EQUATION SEE FIGURE 3.7.2

$$S_c = S_s \left(10^{-\frac{A1 - A14 - AB}{20}}\right)$$

A1 = Attenuation across spacecraft/IUS joint, see Figs 3.13 - .

A14 = Attenuation between spacecraft attach point and RF Switch / Diplexer support.

AB = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface).

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

Subscripts

d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

APPLICABLE ACCELEROMETERS/EQUATIONS

See Figure 3.7.3

$$A14 = 20 \log \frac{(\bar{S}_{Id})_f}{(\bar{S}_{cd})_f}$$

- Assumes S_I same for all longerons
- Shock path 40 in.

QTV ACCELS	
S_I	S_c
1 ART	44 ART
70 ART	

ID	S-C (Inches)	AB (db)	
N29A	37	-0.6	RF Switch
N31A	40	0	RF Switch
N33B	43	+0.7	RF Switch
N36B	46	+1.2	RF Switch
N34A	40	0	Diplexer
N35B	49	+1.8	Diplexer

$$AB = 20 \log \frac{S\text{-}C}{40}$$

S-C = Shock path length from spacecraft source to component.

See Figures 3.7.4 and 3.7.5

$$AN29 = A1 + A14 - 0.6$$
$$AN34 = A1 + A14$$

FINAL EQUATIONS

$$S_{N29A} = S_s \left(10^{\frac{-A1 - A14 + 0.6}{20}}\right)$$

$$S_{N34A} = S_s \left(10^{-\frac{A1 - A14}{20}}\right)$$

Predicted shock spectra shown in Figures 3.7.6 thru 3.7.11.

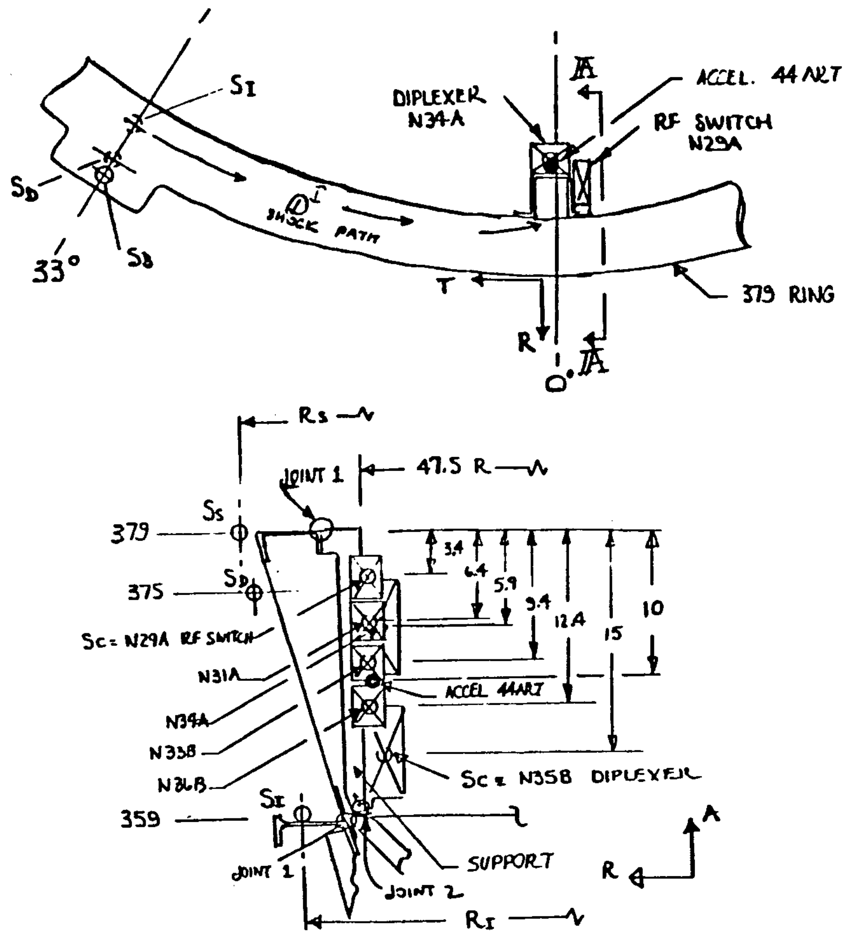
FIGURE 3.7.1
RF SWITCH / DIPLEXER
SHOCK EQUATIONS

E.J. Beck 5/26/82

THE BOEING COMPANY

NUMBER
REV LTR

COMPONENT		LOCATION			SOURCE NEAREST COMPONENT: S_I ~ IUS			SOURCE NEAREST COMPONENT: S_S ~ S/C			PATH LENGTH / NUMBER OF JOINTS	
ID.	NAME	X_C	θ_C	R_C	X_I	θ_I	R_I	X_S	θ_S	R_S	I-C	S-C
N29A	RF SWITCH	376"	358°	47"	359"	33°	51"	379"	33°	56"	47/2	37/1
N31A	↓	373	↓	↓	↓	↓	↓	↓	↓	↓	44/2	40/1
N33B	↓	370	↓	↓	↓	↓	↓	↓	↓	↓	41/2	43/1
N36B	↓	367	↓	↓	↓	↓	↓	↓	↓	↓	38/2	44/1
N34A	DIPLEXER UPPER	373	0°	46.5"	↓	↓	↓	↓	↓	↓	44/2	40/1
N35B	DIPLEXER LOWER	364	0°	46.5"	↓	↓	↓	↓	↓	↓	35/2	49/1



SHOCK PATH CALCULATIONS

IUS SOURCE (S_I) TO NEAREST RF SWITCH (S_C = N36B) = I-C

① From 33° Nut (S_I) thru 359 Ring to 0° — 30"

② Thru Joint 1 to deck, thru Joint 2 into support, up support to N36b — 8"

SPACECRAFT SOURCE (S_S) TO NEAREST RF SWITCH (S_C = N29A) = S-C

① From Spacecraft Attach Point at 33° (S_S) thru 379 Ring to 0° — 32"

② Thru Joint 1 to Support, 1 down Support to N29A — 5"

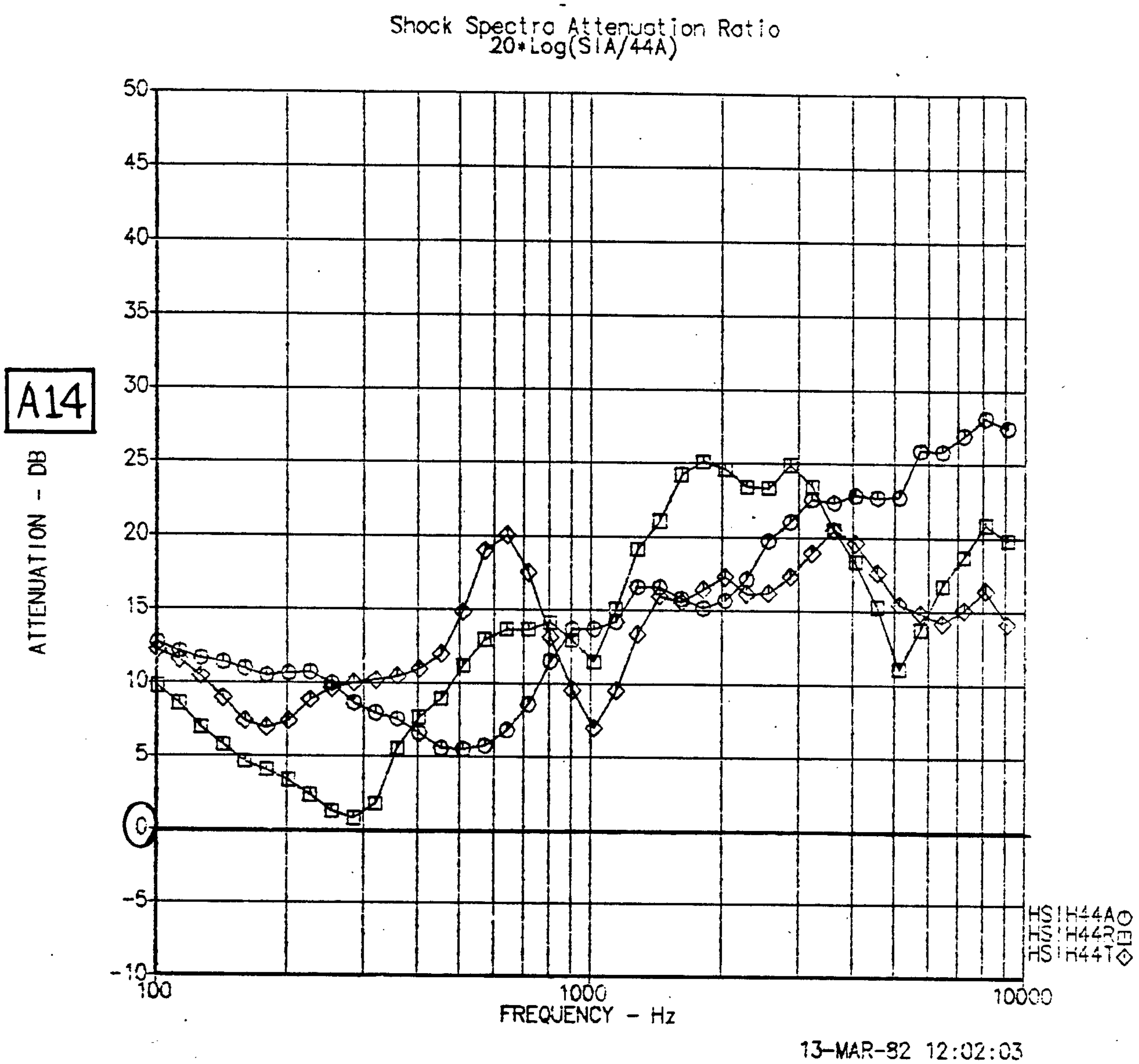
GTV INSTRUMENTATION		
NO.	I-M	S-M
44 ART	40/2	44/1

I-M = Shortest path from SI to Accel. (M)/No. of joints
S-M = Shortest path from Ss to Accel. (M)/No. of joints
A = Axial R = Radial
T = Tangential

FIGURE 3.7.2
RF SWITCH/DIPLEXER
SHOCK PATHS

CBeck 4/26/82

○ A14A (Axial) = HSI H44A. DB
□ A14R (Radial) = HSI H44R. DB
◇ A14T (Tangential) = HSI H44T. DB



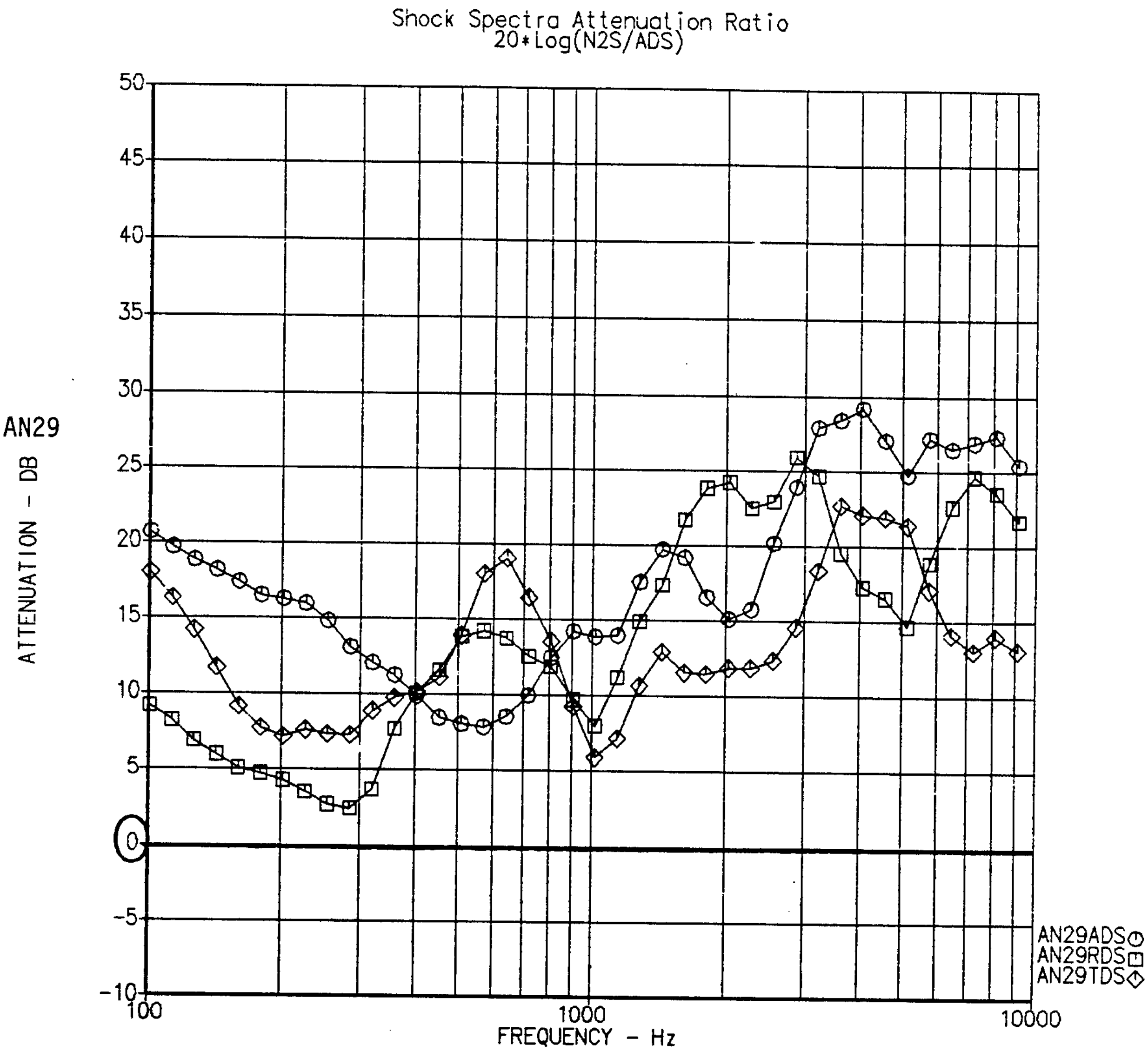
ATTENUATION A14
BETWEEN SPACECRAFT ATTACH POINT AND RF/SWITCH / DIPLEXER SUPPORT

AXIAL
RADIAL
TANGENTIAL

CALC	GB	13MAR82	REVISED	DATE	FIGURE 3.7.3	
CHECK						
APPD.					THE BOEING COMPANY	PAGE D-72
APPD.						

AN 29 * = AN29*DSP.DB = A1* + A14* - 0.6

* = A, R or T



15-MAY-82 11:26:04

ATTENUATION AN29

SPACECRAFT ADAPTER AT 33^0

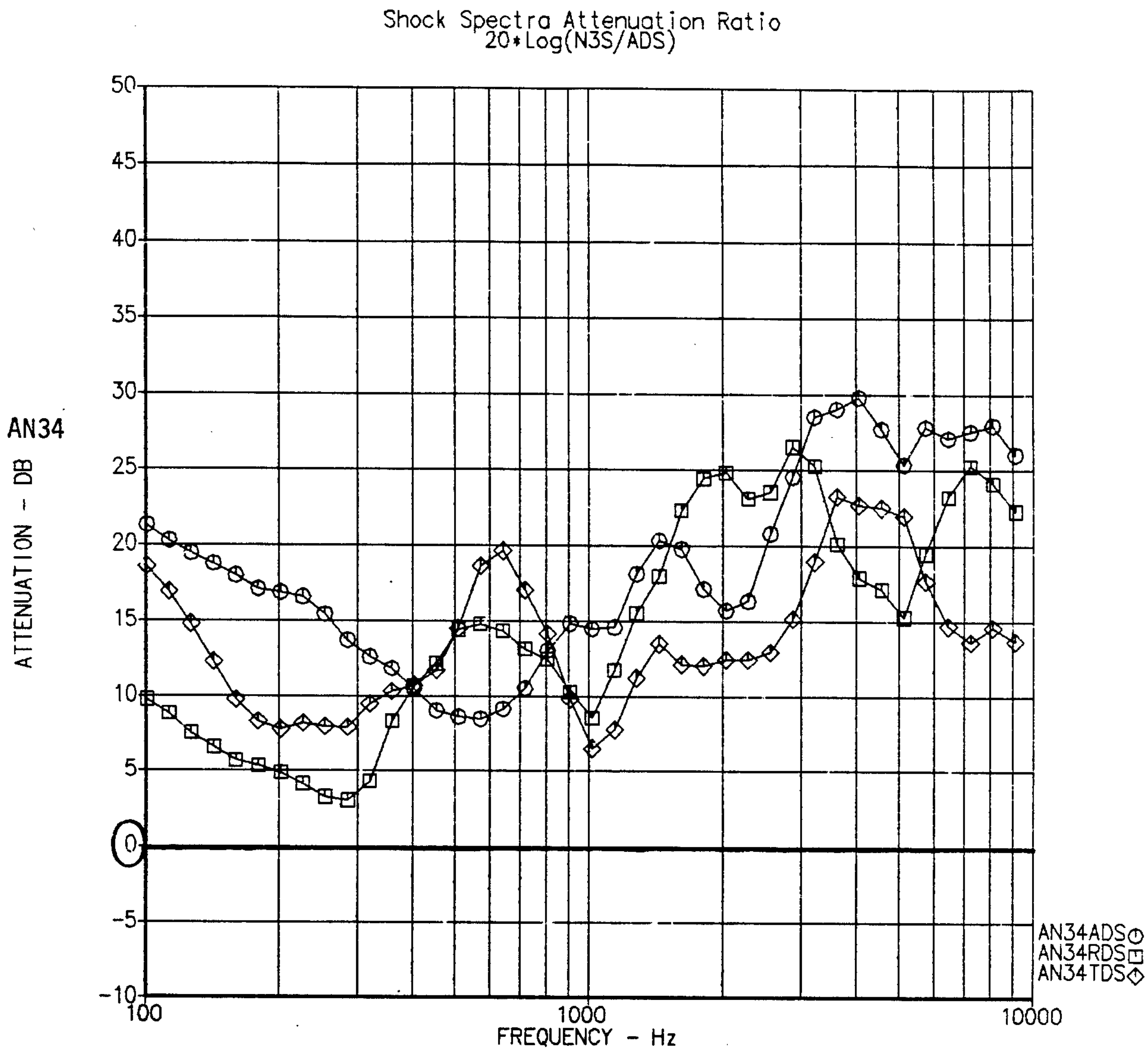
TO RF SWITCH, N29, AT 0^0

○ Axial, AN29A
□ Radial, AN29R
◇ Tangential, AN29T

CALC	CB	15MAY82	REVISED	DATE		
CHECK					FIGURE 3.7.4	
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-73

AN34* = AN34*DSP.DB = A1* + A14*

* = A, R or T



15-MAY-82 11:27:00

ATTENUATION AN34

SPACECRAFT ADAPTER AT 33^{o}

TO DIPLEXER, N34, AT 0^{o}

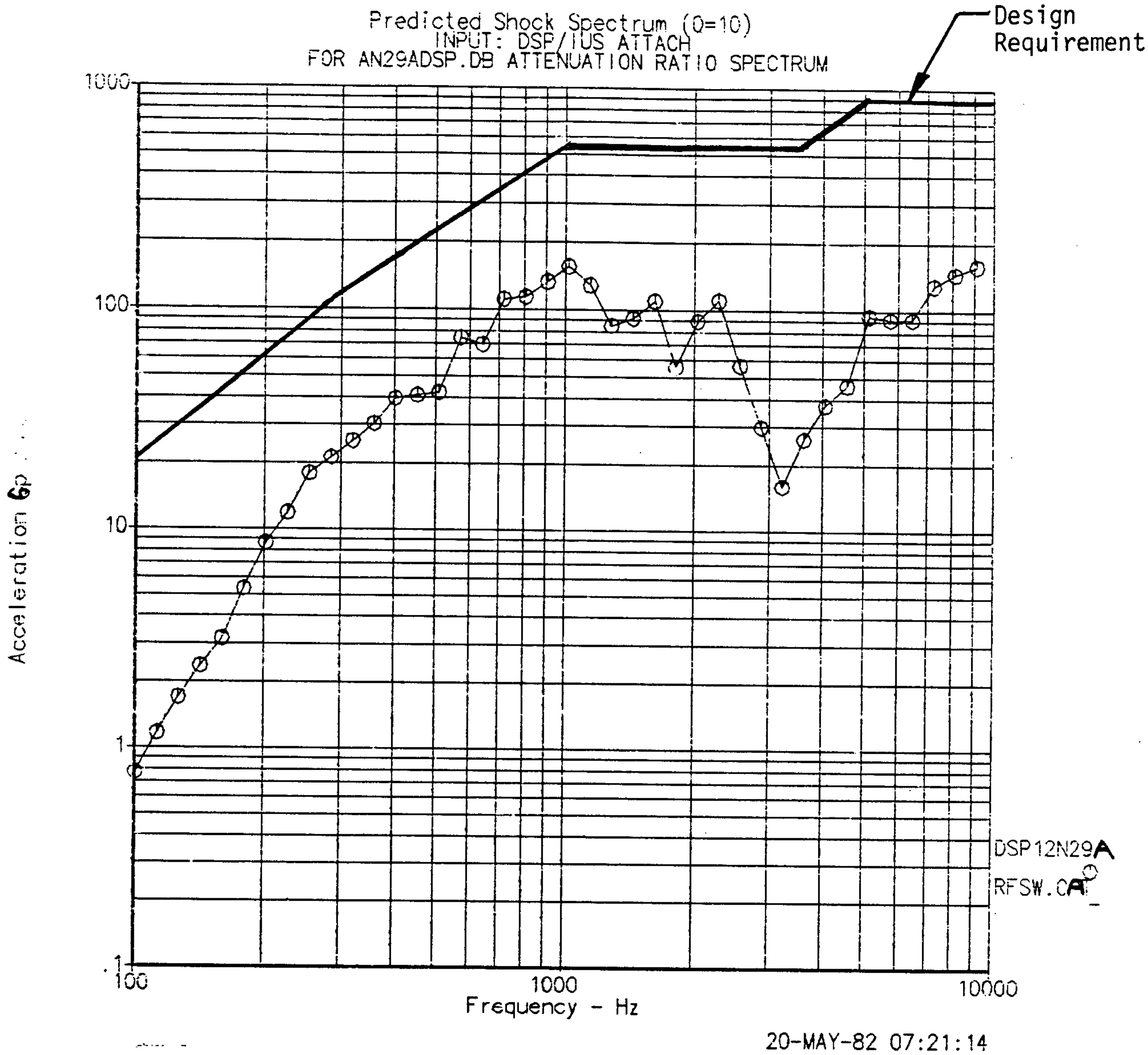
O Axial, AN34A

□ Radial, AN34R

◇ Tangential, AN34T

CALC		15MAY82	REVISED	DATE	FIGURE 3.7.5	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-74

$$DSP12N29A. = S_s(10^{-AN29A/20})$$



DSP 12,13 INDUCED SHOCK
AT RF SWITCH LOCATION, N29

O Axial

CALC	OB	20MAY82	REVISED	DATE	FIGURE 3.7.6	
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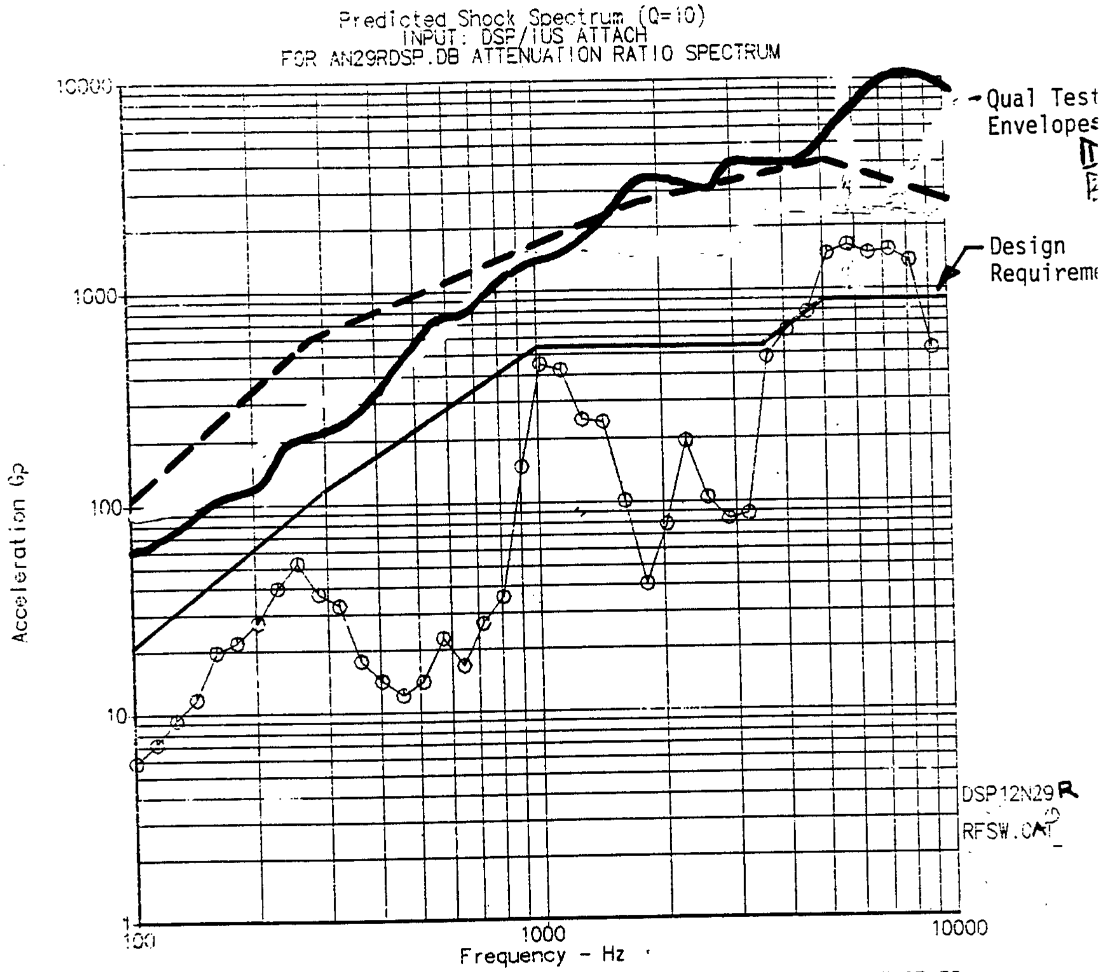
DSP12N29R. = S_s (10 $^{-AN29R/20}$)



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DSP 12,13 INDUCED SHOCK

AT RF SWITCH LOCATION, N29

O Radial

1. Boeing Memo 2-3612-IUS-836, "RF Switch Pyro Shock", 28 March 1983.

2. Transco Document No. QTR 2654, "Qualification Test Report for RF Coaxial Switch, BAC Part No. 280-41009-102", Revision B, 26 June 1984, Transco Products Inc., Marina del Rey, CA.

CALC		20MAY82	REVISED	DATE	FIGURE 3.7.7	
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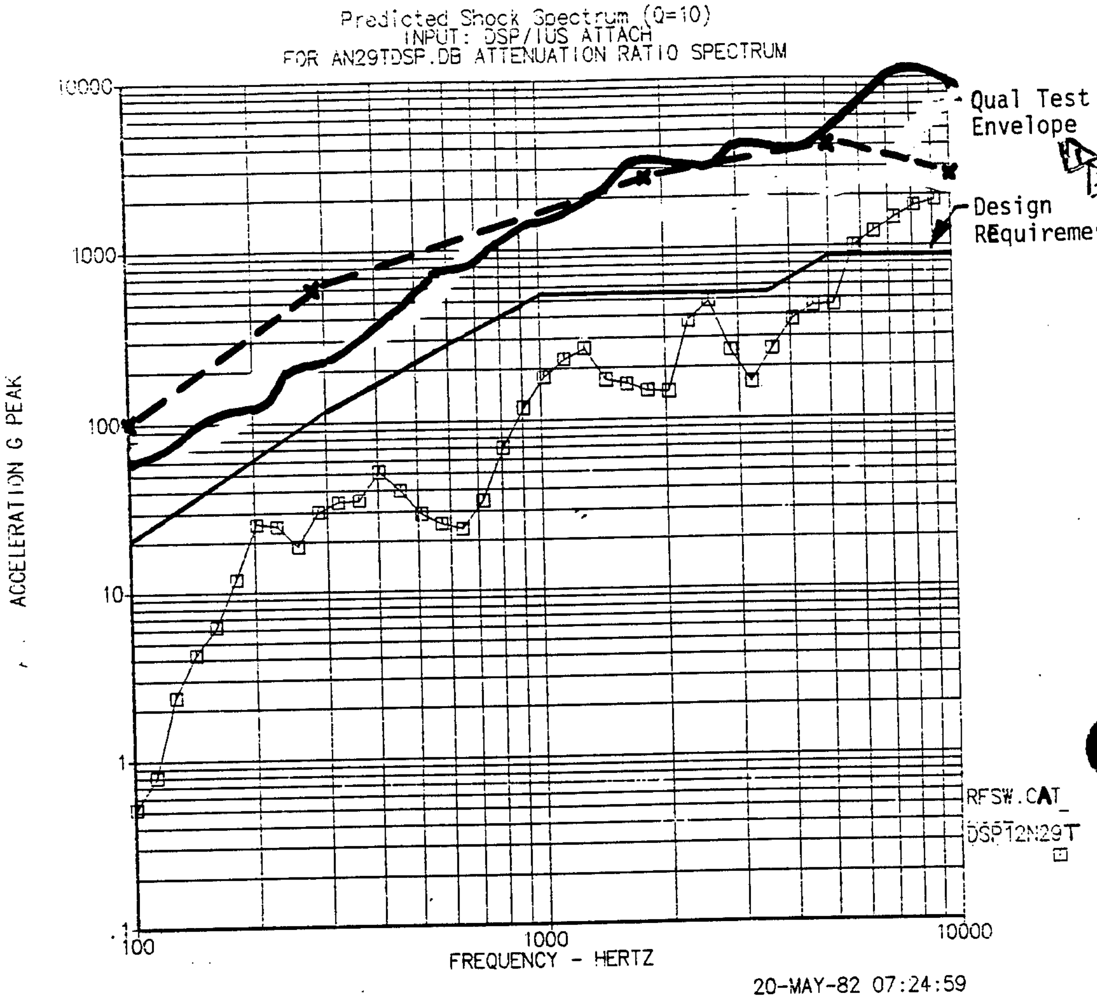
DSP12N29T. = $S_s(10^{-AN29T/20})$



DSP 12,13 INDUCED SHOCK
AT RF SWITCH LOCATION, N29

□ Tangential

1. Boeing Memo 2-3612-IUS-836, "RF Switch Pyro Shock", 28 March 1983.
2. Transco Document No. QTR 2654, "Qualification Test Report for RF Coaxial Switch, BAC Part No. 280-41009-102", Revision B, 26 June 1984, Transco Products Inc., Marina del Rey, CA.

CALC	CYS	20MAY82	REVISED	DATE	FIGURE 3.7.8	
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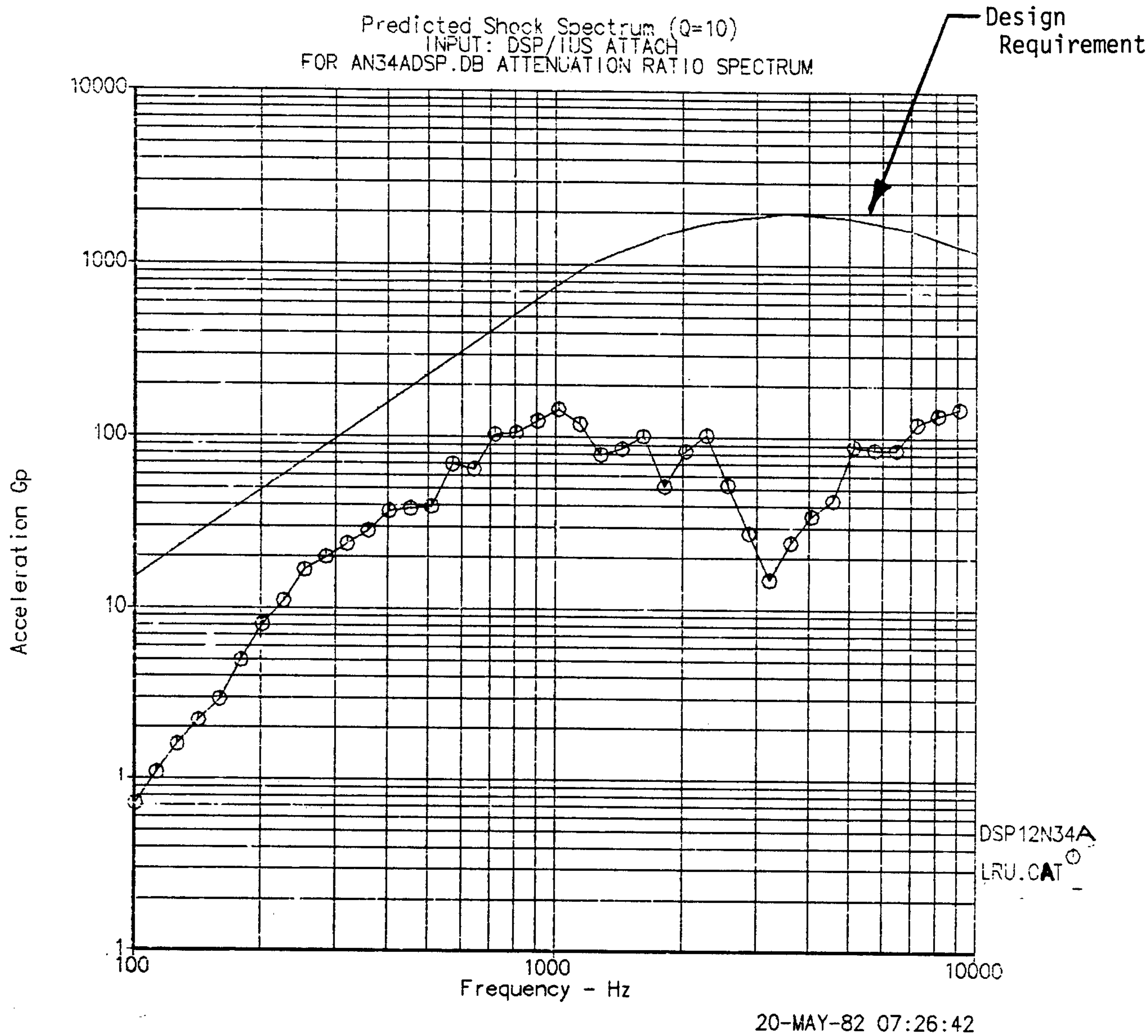
$$DSP12N34A. = S_s(10^{-AN34A/20})$$



DSP 12,13 INDUCED SHOCK

AT DIPLEXER LOCATION, N34

O Axial

CALC	OB	20MAY82	REVISED	DATE	FIGURE 3.7.9	
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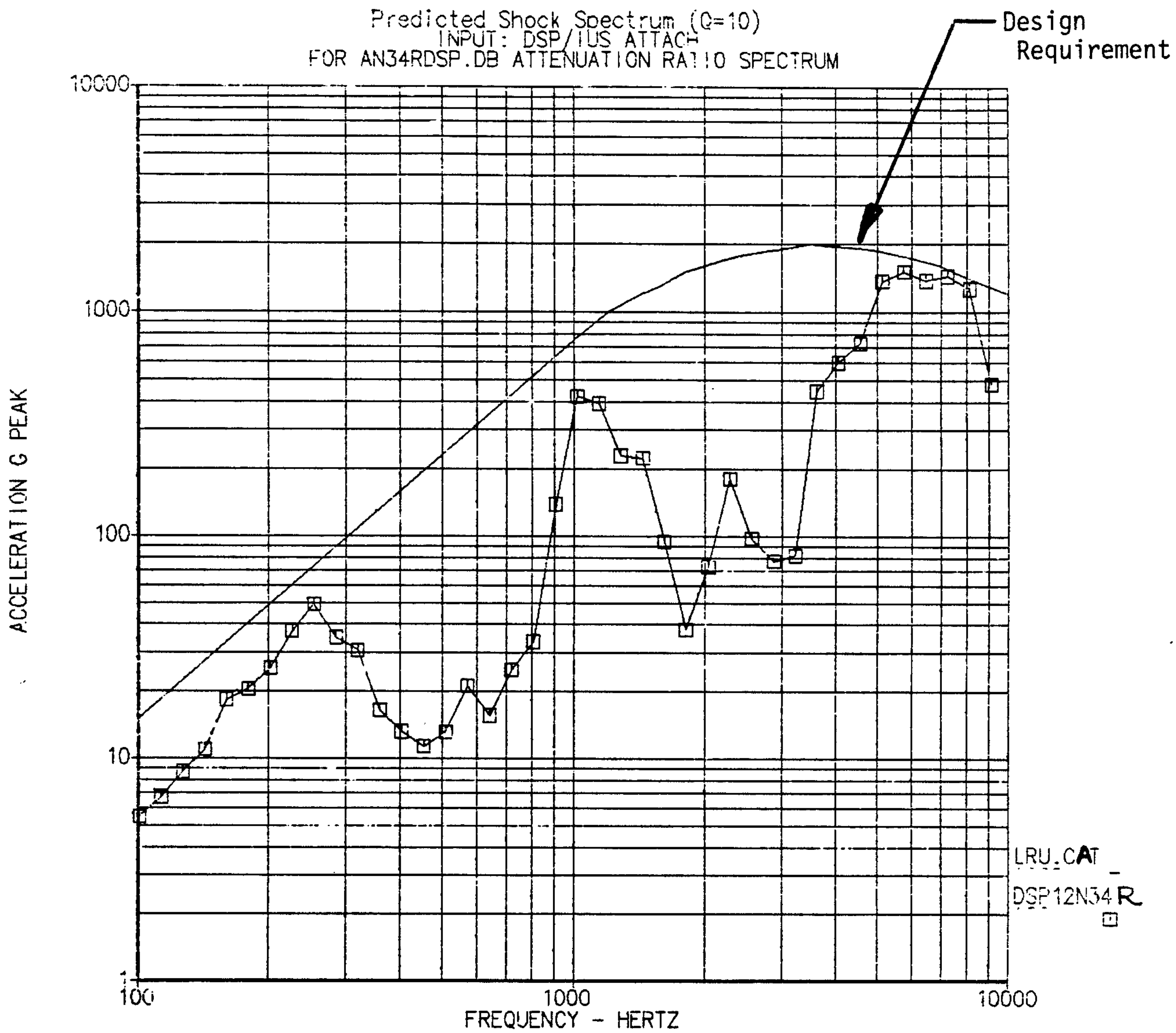
$$DSP12N34R = S_s(10^{-AN34R/20})$$



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DSP 12,13 INDUCED SHOCK

AT DIPLEXER LOCATION, N34

☐ Radial

CALC	CB	20MAY82	REVISED	DATE	FIGURE 3.7.10	
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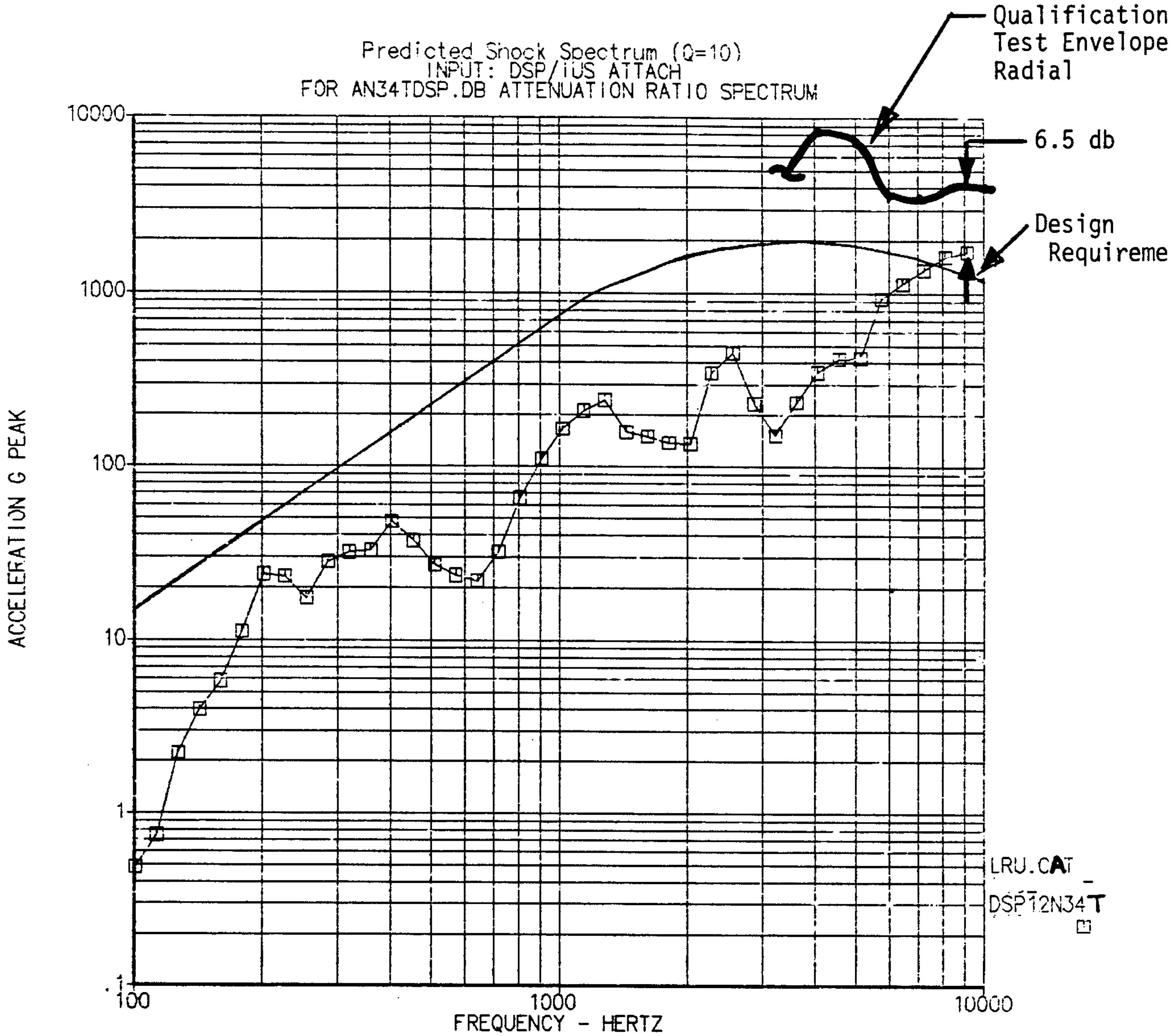
DSP12N34T. = $S_s(10^{-AN34T/20})$



DSP 12,13 INDUCED SHOCK

AT DIPLEXER LOCATION, N34

⊟ Tangential

CALC	CB	20MAY82	REVISED	DATE	FIGURE 3.7.11	
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3.8 Shock Prediction, Medium Gain Antenna*, EMU Transducers*

The equations and data used to predict the shock spectra for the Medium Gain Antenna and EMU Transducers are shown on Figure 3.8.1. Equipment locations are shown on Figure 3.8.2. Only the EMU shock transducers are considered for this analysis since the EMU vibration transducers are not required to function at the time of spacecraft separation. The predicted spectra are shown in Figures 3.8.5, 3.8.6 and 3.8.7.

*Antenna, BAC Drawing 290-27106
EMU Transducers, BAC Drawing 290-22228

GENERAL EQUATION   SEE FIGURE 3.8.2

$S_C = S_S \left(10^{\frac{-A1-A15-AB}{20}}\right)$ Antennas N78 & N80 $S_C = S_S$ - Shock Accels N86, N87

A1 = Attenuation across spacecraft/IUS joint, see Figures 3.1.3,

A15 = Attenuation between spacecraft attach point and Antenna N78 location.

AB = Attenuation correction for distance.

APPLICABLE ACCELEROMETERS/EQUATIONS/DATA

See Figure 3.8.3

$$A15 = 20 \log \frac{(\bar{S}_{65d})_f}{(\bar{S}_{09d})_f}$$

Shock path = 16 in.

QTV ACCELS	
65A,R	09A,R

$$AB = 20 \log \frac{S-C}{16}$$

See Figure 3.8.4

$$AN78 = A1 + A15$$

FINAL EQUATIONS

$S_{N78} = S_S \left(10^{\frac{-A1-A15}{20}}\right)$ See Figure 3.8.5

$S_{N80} = S_S \left(10^{\frac{-A1-A15-2B}{20}}\right)$

$S_{N86} = S_{N87} = S_S$ See Figure 3.8.6

DEFINITIONS

S_C = Shock level on Component (Calculated)

S_{NX} = Shock level on Specific Component, NX (Calculated)

S_D = Spacecraft Induced Shock Level defined to exist at IUS Station 375 (4 inches on IUS side of Spacecraft/IUS Interface). See Figure 1.

S_I = IUS Induced Shock Level measured on IUS Longeron about 4 inches above Station 359 Separation Nuts

S_S = Spacecraft Shock Source located at Spacecraft/IUS Interface locations at IUS Station 379. See Figure 3.0.

A = Calculated Attenuation in decibels

$\bar{S}$ = Average of valid shock spectra from IUS separation nut Pulses 1 and 2 recorded during QTV Pyrotechnic Shock Tests 1,2 and 3.

B = Attenuation correction for distance. Assume shock attenuation increases linearly with distance.

Subscripts

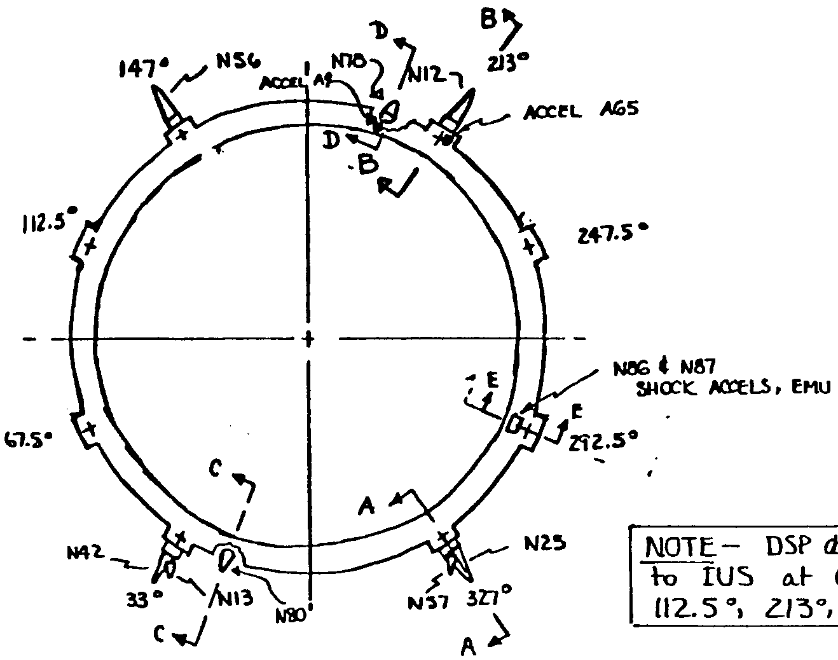
d = Shock direction (A = Axial, R = Radial, T = Tangential)

f = 1/6 octave band center frequencies

FIGURE 3.8.1
ANTENNA AND
EMU SHOCK ACCELEROMETER
SHOCK EQUATIONS

MBuck 5/26/82

NUMBER
REV LTR



	ID.	NAME	LOCATION X_C	θ_C	R_C	SOURCE NEAREST COMPONENT S_I ~ IUS X_I	θ_I	R_I	S_D ~ S/C X_D	θ_D	R_D	PATH LENGTH / NUMBER OF JOINTS I-C	S-C
STS	N12	OMNI ANTENNA	370"	213°	60"	359"	213°	51	379"	213°	55"	17/1	
	N13	MED. GAIN ANT.	375	33	60	↓	33	↓	↓	33	↓	21/1	
	N25	OMNI ANT.	370	327	60"	↓	327	↓	↓	292.5	↓	17/1	
	N42	OMNI ANT.	370	33°	60	↓	33	↓	↓	33	↓	17/1	
	N56	OMNI ANT.	370	147°	60	↓	147	↓	↓	112.5	↓	17/1	
	N57	MED. GAIN ANT.	375	327	60	↓	327	↓	↓	292.5	↓	21/1	
T34D	N78	MED. GAIN ANT.	375	200	50	↓	213	↓	↓	213	↓	37/1	16/1
	N80	MED. GAIN ANT.	369	20	50	↓	33°	↓	↓	33	↓	42/1	22/1
	N86	SHOCK ACCEL.	379	292.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1
	N87	SHOCK ACCEL	379	292.5	50	↓	292.5	↓	↓	292.5	↓	22/2	2/1

NOTE – DSP attachs to IUS at θ = 33°, 112.5°, 213°, 292.5°

I-C = Shock path length from IUS Separation Nut to Component

S-C = Shock path length from Spacecraft Attach point to Component

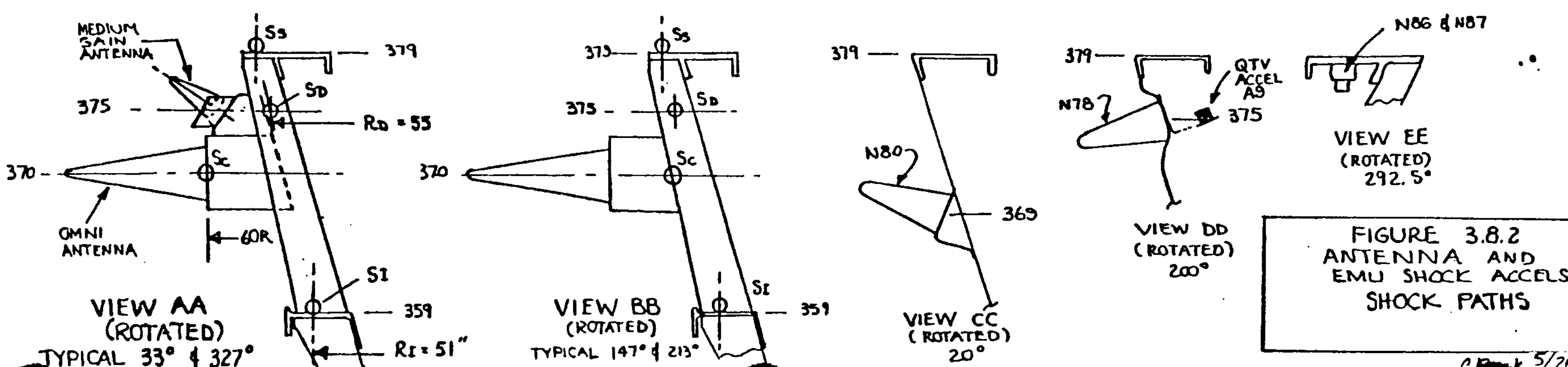
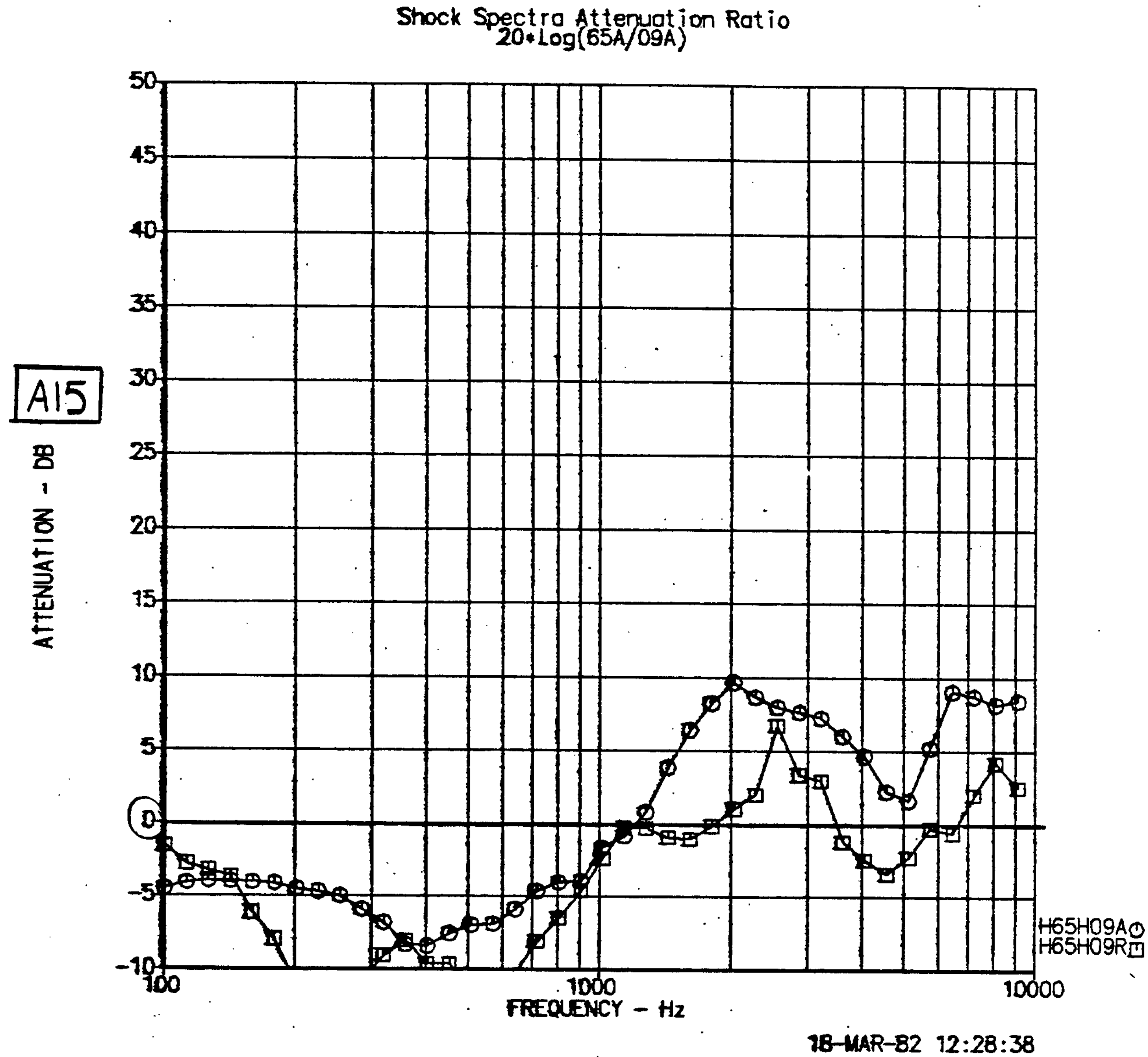


FIGURE 3.8.2
ANTENNA AND
EMU SHOCK ACCELS
SHOCK PATHS

○ A15A (Axial)
□ A15R (Radial) } = H65H09 * . DB
* = A or R



ATTENUATION A15
BETWEEN SPACECRAFT ATTACH POINT
AND MEDIUM GAIN ANTENNA N78

AXIAL
RADIAL

CALC	O/S	18MAR82	REVISED	DATE	FIGURE 3.8.3
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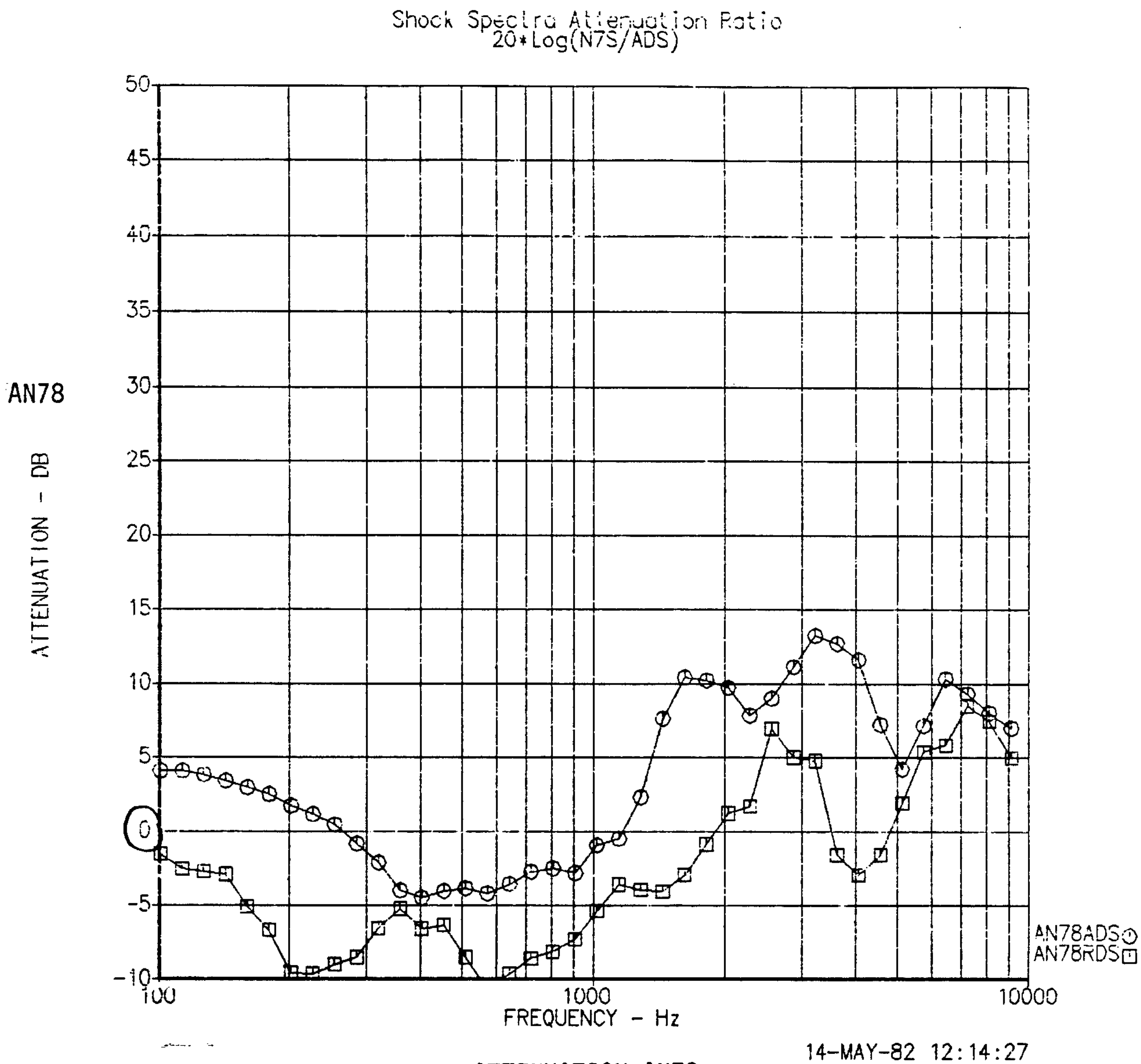
			D290-75303-2 A	Vol. II THE BOEING COMPANY	PAGE D-84

AN78* = A1* + A15*

* = A or R



ATTENUATION AN78

SPACECRAFT ADAPTER AT 213°

TO MEDIUM GAIN ANTENNA, N78, AT 200°

○ Axial, AN78A

□ Radial, AN78R

CALC	CB	14MAY82	REVISED	DATE	FIGURE 3.8.4	
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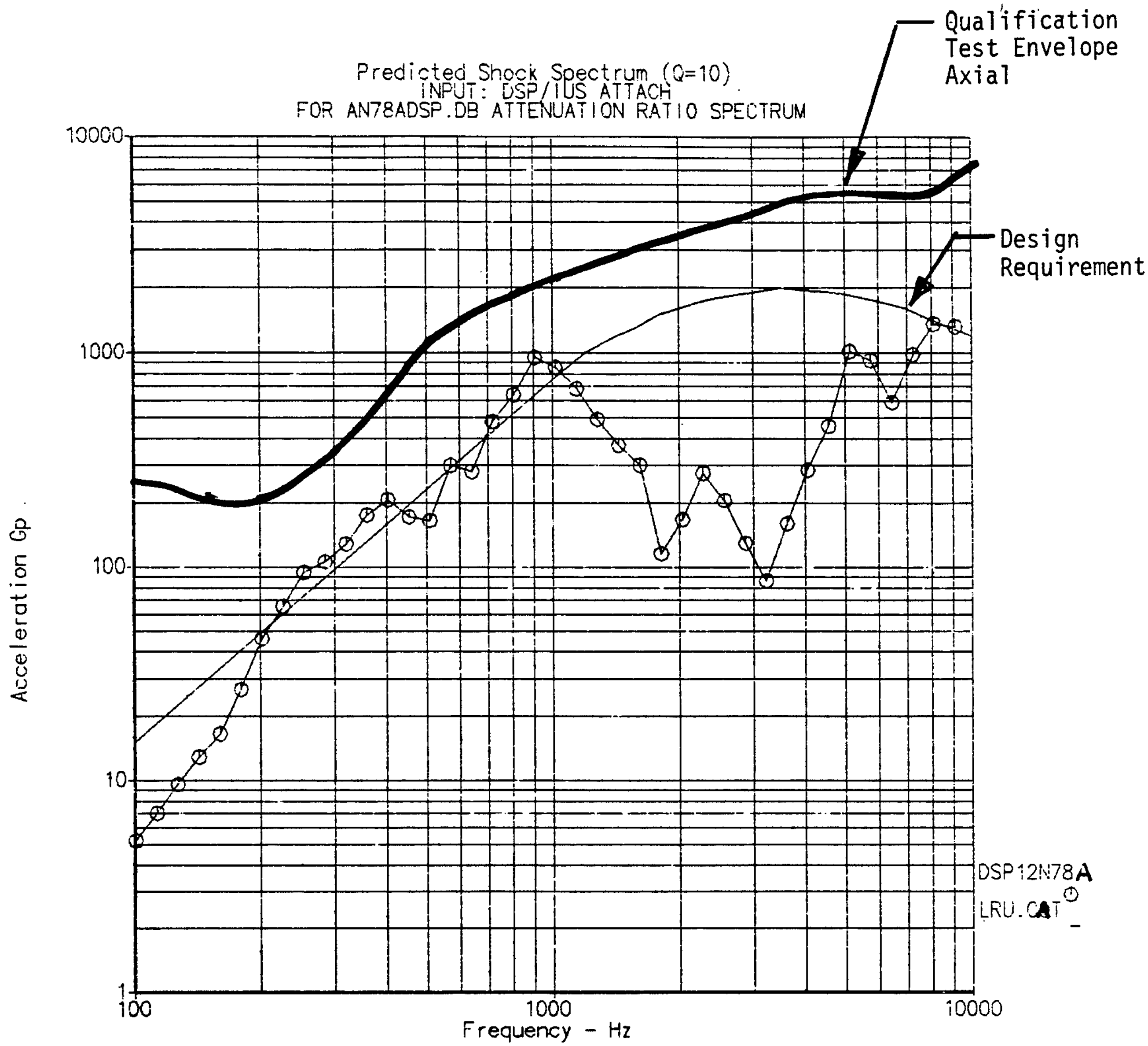
$$DSP12N78A. = S_s(10^{-AN78A/20})$$



DSP 12, 13 INDUCED SHOCK

AT MEDIOM GAIN ANTENNA LOCATION, N78

O Axial

CALC	CB	20MAY82	REVISED	DATE	FIGURE 3.8.5	
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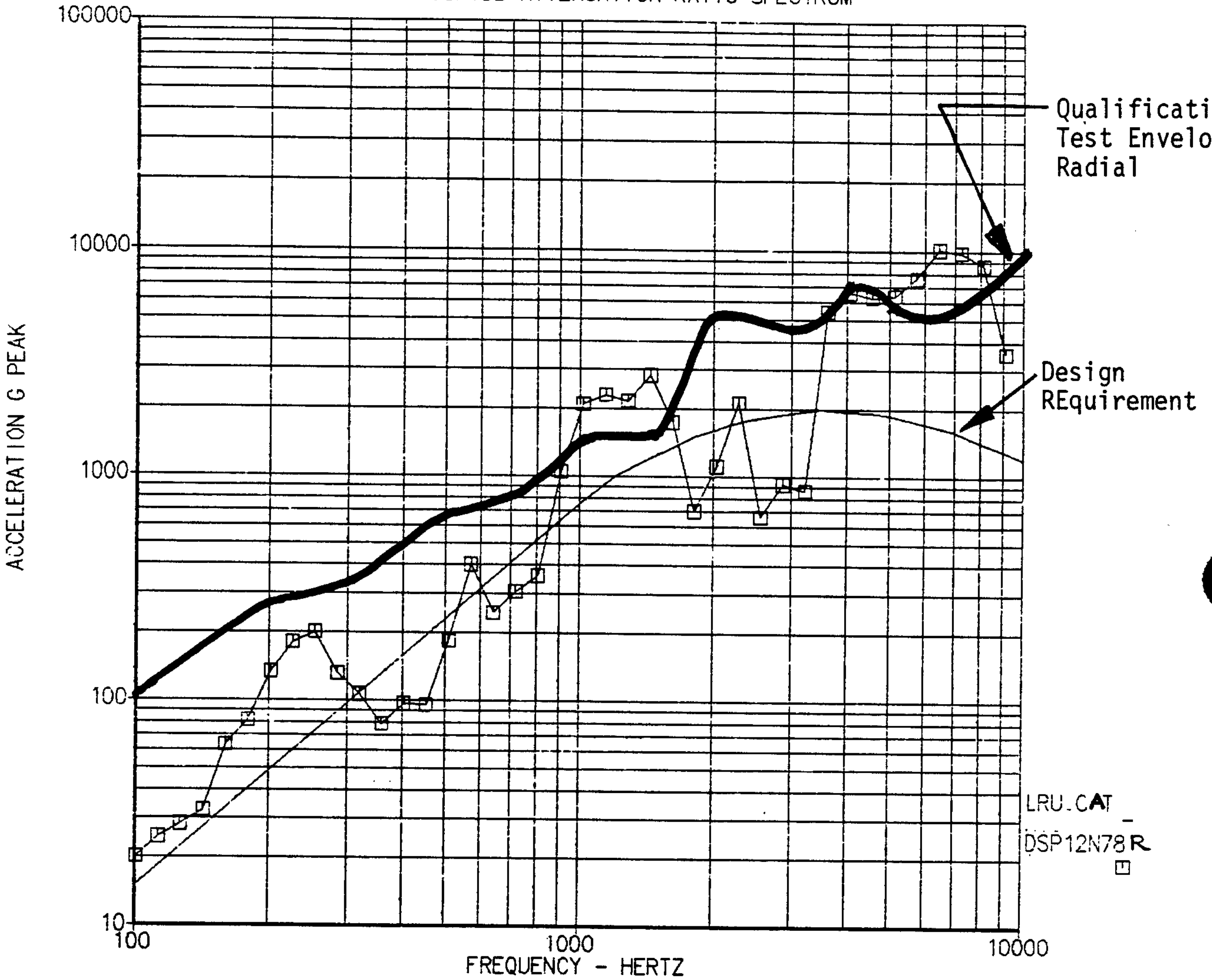
$$DSP12N78R. = S_s\ (10^{-AN78R/20})$$

Predicted Shock Spectrum (Q=10)
INPUT: DSP/IUS ATTACH
FOR AN78RDSP.DB ATTENUATION RATIO SPECTRUM



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DSP I2,13 INDUCED SHOCK

AT MEDIUM GAIN ANTENNA LOCATION, N78

□ Radial

CALC		20MAY82	REVISED	DATE	FIGURE 3.8.6	
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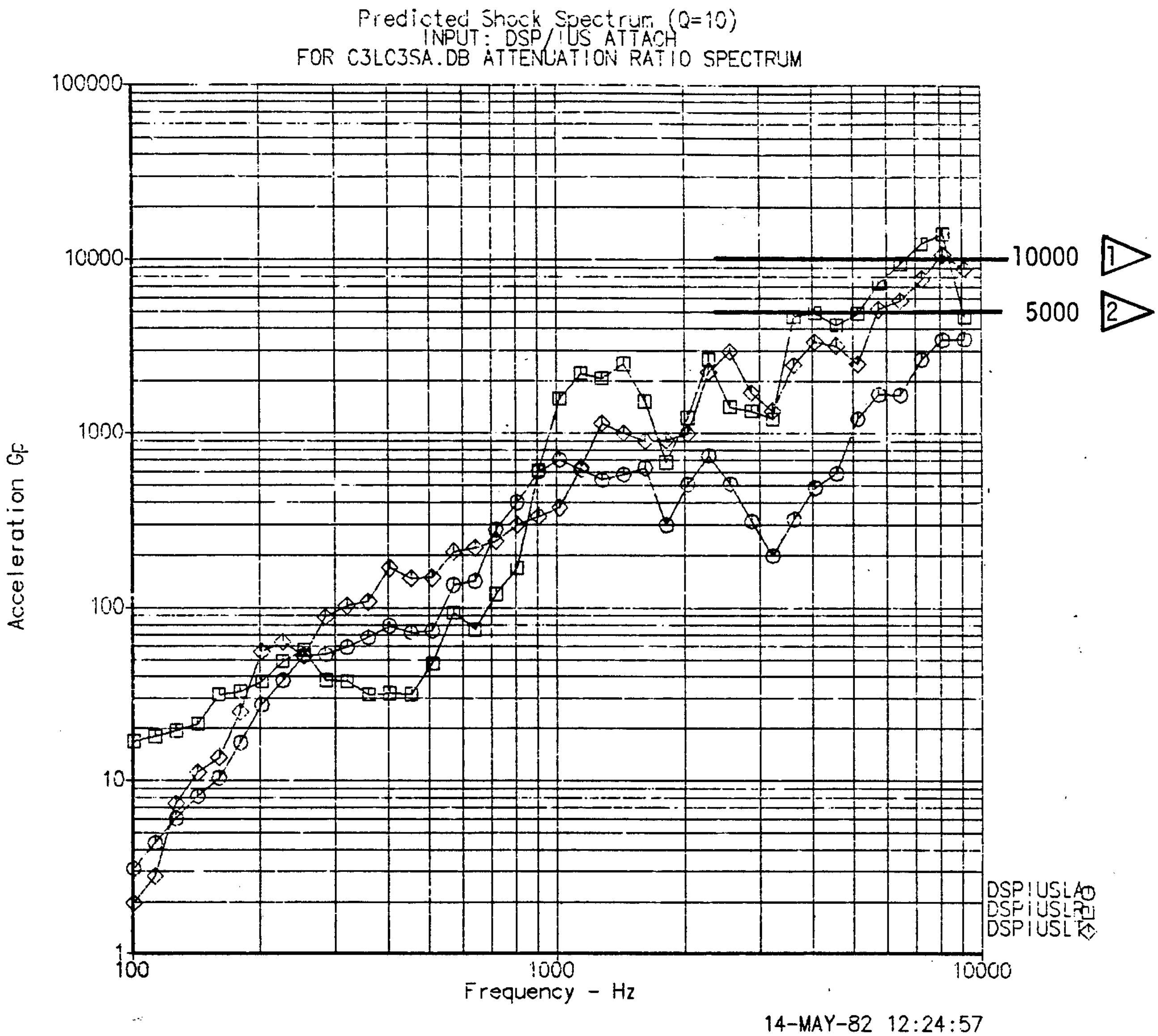
DSPIUSL*. = $(10^{-A1*/20})$

* = A,R or T

1 Design requirement in accelerometer sensitive axis

2 Design requirement in accelerometer transverse axis



DSP 12,13 INDUCED SHOCK

AT EMU ACCELEROMETER LOCATIONS, N86 and N87

○ Axial
□ Radial
◇ Tangential

CALC	CB	14MAY82	REVISED	DATE		
CHECK					FIGURE 3.8.7	
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4.0 CONCLUSIONS

All IUS components are compatible with R
DSP 12,13 induced shock. Rationale for this conclusion follows.

1. Figures 3.1.12, 3.1.13 and 3.1.14 compare the predicted DSP induced shock on the REM with the shock applied during the REM component qualification tests. The qualification environment is not 6 db higher than the predicted levels as noted on figures 3.1.13 and 3.1.14. However, the REM is considered to be compatible with the DSP 12, 13 shock for the following reasons.

   (a) The low margins are at frequencies above 1000 Hz. Since the REM is mounted on vibration isolators, the pyro shock levels transmitted to the REM will be reduced

   (b) The REM is a mechanical device. Mechanical devices are usually not susceptible to high frequency shock. The REM did experience valve chatter at 240 Hz and 540 Hz during vibration testing. The vibration isolators were added to eliminate the valve chatter. R

   (c) The minimum margins are positive and occur over narrow frequency bands.

2. The RF Switch and Fail Safe RF Relay have a 6 db margin over the predicted DSP induced shock, Figures 3.7.7 and 3.7.8.

3. The Medium Gain Antenna is considered to be compatible with the DSP induced environment even though the predicted levels exceed the component qualification levels, see Figure 3.8.6. The antenna is a simple device with no moving parts, Figure 4.1. Pyro shock tests for antennas are optional per.MIL-STD-1540A, Table II.

4. The EMU shock accelerometer is considered to be compatible with the DSP induced environment even though the predicted levels exceed the design requirement, see Figure 3.8.7. Piezoelectric accelerometers are inherently rugged devices and should easily withstand the predicted level. Also loss of the accelerometers will not affect IUS function.

5. The DSP induced shock is greater than the Computer and Diplexer design requirement. The qualification test levels are 6db higher than the predicted environments (Figures 3.2.7 and 3.7.11). Therefore, the computer and diplexer are compatible with the DSP 12,13 shock.

6. All other component analyses show the predicted DSP 12,13 induced shock to be less than the component design requirement.

DSP induced shock is greater than the IUS allowable at a point on the IUS 4 inches from the IUS/DSP interface, see Figures 5.4.1 and 5.4.2. R

D

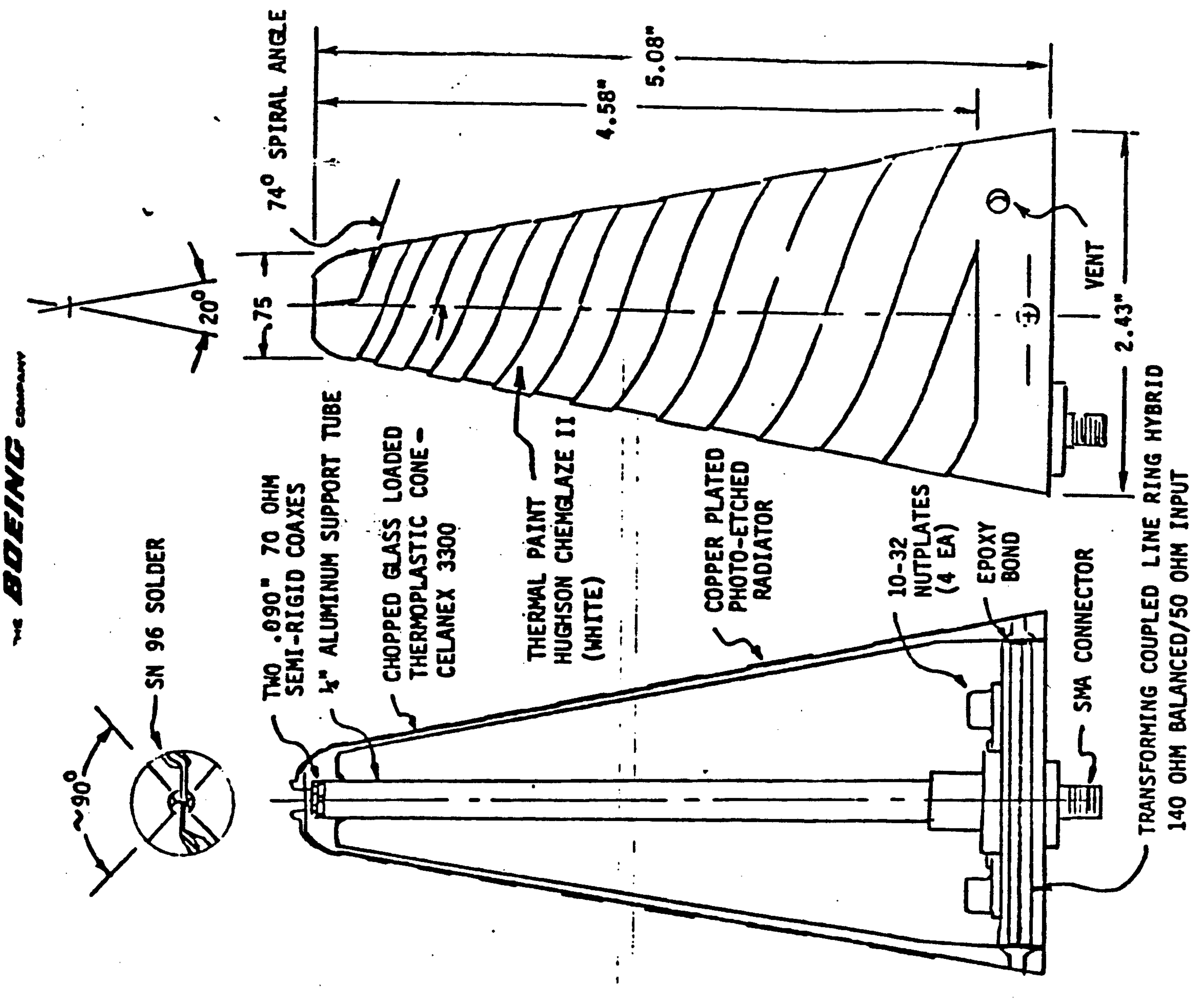

FIGURE 4.1

MEDIUM GAIN ANTENNA

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Page 94, Figure 4.4 Deleted

Page 95, Figure 4.5 Deleted

Page 96, Figure 4.6 Deleted

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5.0 APPENDIX, DSP INDUCED SHOCK ESTIMATE

The DSP induced shock spectra shown in Figure 3.0 were estimated as described in this section.

5.1 DSP Separation Shock Test

A separation shock test was conducted in 1970 using the DSP Qualification Spacecraft (Q-1), a Transtage Adapter Assembly and the Martin-Marietta Interstage Adapter Assembly (AC-2). Twelve accelerometers were located about 2 inches from the DSP separation nuts (4 locations, 3 accelerometers at each location). A typical location is shown in Figure 5.1.1. Two separation events were performed by simultaneously firing the eight cartridges in the four separation nuts. The cartridges were loaded to 120% of nominal charge. The DSP adapter did not separate (fall away) from the DSP after the separation nuts were fired. The shock spectra from the DSP adapter accelerometers were enveloped and are shown in Figure 5.1.2.

Six accelerometers were located on the Transtage Adapter Assembly longerons 4 inches from the DSP/Transtage Adapter interface (2 locations, 3 accelerometers per location). The DSP induced shock spectra on the Transtage longeron are shown in Figure 5.1.3.

5.2 Interface Shock Estimate

The DSP induced shock spectra required for this analysis are the spectra for a location on the DSP adapter, immediately adjacent to the DSP/IUS interface (refer to Ss defined in Section 3.0 and Figure 5.1.1). The required spectra are not directly available from the 1970 DSP/Transtage test. Therefore, Ss was estimated using the following equation.

$$Ss = (St)(TF_{DSCS})$$

Ss = Shock spectrum on the DSP adapter immediately adjacent to the DSP/IUS interface, Figure 3.0.

St = Shock spectrum measured on the transtage longeron during the 1970 DSP separation shock test, Figure 5.1.3.

TF_{DSCS} = Transfer function between the base of the DSCS bipod adapter and the transtage longeron determined from 1981 DSCS separation shock test, references 6 and 7.

The transfer function, TF_{DSCS}, is the inverse of the attenuation calculated from measured shock spectra from the 1981 DSCS separation shock test.

Reference 6 - General Electric PIR U-1R44-DSCS-898, Shock Data on Transtage Simulator (AC-2) During DSCS III/Bipod Separation Tests, 2 March 1981

Reference 7 - General Electric Letter CTR-6048; to Lt. L. Reagan from G.H.Hoke; subject, Transmittal of DSCS III Qual Satellite/AC-2 Separation Shock Data, Contract FP4701-77-C-0036, 5 April 1982.

5.2 Interface Shock Estimate (Cont'd)

$$A_{DT} = 20 \log \frac{\text{DSCS (Figure 5.2.2)}}{\text{Transtage (Figure 5.2.3)}}$$

A_{DT} = Attenuation between the DSCS Bipod Foot and Transtage Longeron, 4 inches from the interface, Figure 5.2.1.

$$TF_{DSCS} = 10^{-\frac{(-A_{DT})}{20}}$$

$$Ss = St\ (10^{\frac{A_{DT}}{20}})$$

Ss shown in Figure 3.0.

St shown in Figure 5.1.3

5.3 Rationale for Interface Shock Estimate

The rationale for estimating the interface shock is presented in the following paragraphs.

1. There is no measured data immediately adjacent to the DSP/Transtage interface from the 1970 test.

2. The validity of the shock spectra from the DSP adapter (Figure 5.1.2) is questionable. The data appears to be in the noise floor below 1000 HZ. A comparison of the attenuation spectra from the DSP/AC-2 test with similar spectra from CS3/IUS and DSCS/AC-2 shock tests indicate the presence of noise in the DSP adapter spectra, see Figures 5.3.1, 5.3.2, 5.3.3. Note the similar shape of the spectra but the DSP attenuation values are in the order of 20 db higher below 1000 Hz. Attenuation values of 30 to 40 db are not reasonable for this type structure. Therefore, the assumption that the DSP adapter spectra are invalid because of noise is reasonable.

3. The transfer function, TF_{DSCS}, calculated from DSCS test data is applicable to the DSP since the AC-2 Transtage was used in both the DSP and DSCS test.

4. The Transtage Longeron shock spectra from the 1970 DSP test appear to be valid above 100 HZ (Figure 5.1.3). The spectra have the characteristic 10 db/octave slope. Compare Figures 5.1.3 and 5.2.3.

5. The DSCS shock spectra, Figures 5.2.2 and 5.2.3, used to calculate TF_{DSCS} appear to be valid above 100 HZ. The DSCS bipod foot is about 20 inches from the DSCS separation nut thus minimizing the low frequency noise problem which invalidated the DSP adapter data (Figure 5.1.2).

5.4 Comparison DSP 12, 13 Induced Shock with IUS Allowable

Figures 5.4.1 and 5.4.2 compare the DSP 12, 13 induced shock with the IUS allowable shock at a location on the IUS longeron, 4 inches from the IUS/DSP interface. The DSP induced shock was calculated by attenuating the shock on the DSP adapter by the transfer functions from the CS3/IUS DTV test.

$$S_{DSP} = Ss\ (10^{-\frac{A1*}{20}})$$

S_{DSP} = DSP 12, 13 induced shock on IUS longeron, 4 inches from interface. Figures 5.4.1 and 5.4.2.

Ss = DSP 12, 13 induced shock on the DSP adapter. Figure 3.0.

A1* = Attenuation across CS3/IUS joint,
* = A, R or T. Figure 3.1.3.

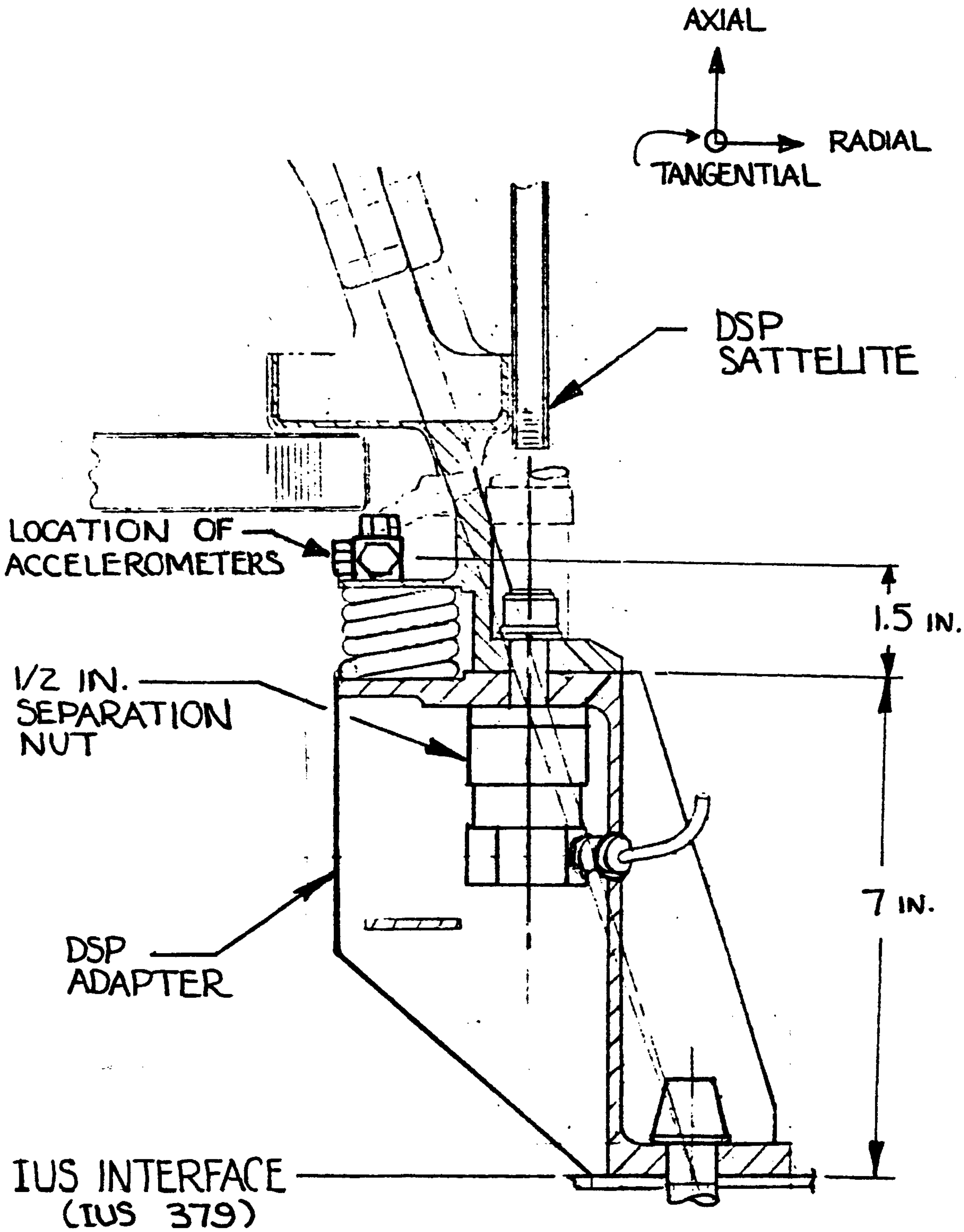
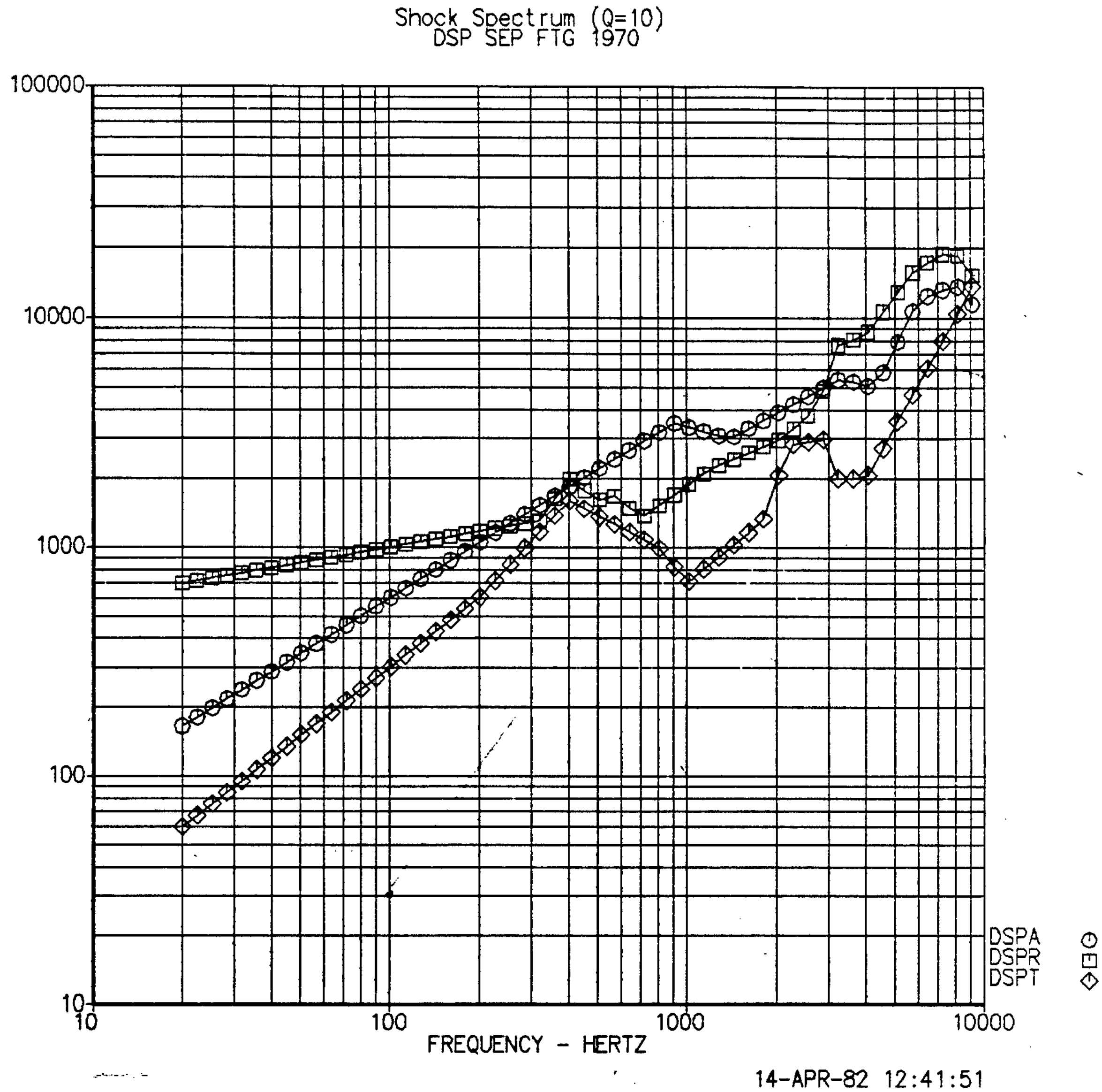


FIGURE 5.1.1
DSP ADAPTER ASSEMBLY
ACCELEROMETER LOCATION

○ Axial, envelope of accelerometers 12, 15, 18, 21 (HDSP12A)
□ Radial, envelope of accelerometers 10, 13, 16, 19 (HDSP12R)
◇ Tangential, envelope of accelerometers 11, 14 17, 20 (HDSP12T)



DSP 12, 13 ADAPTER ASSEMBLY RESPONSE
TO DSP SEPARATION NUT FIRING
(1970 TEST)

○ Axial
□ RAdial
◇ Tangential

CALC	CB	14APR82	REVISED	DATE	FIGURE 5.1.2	
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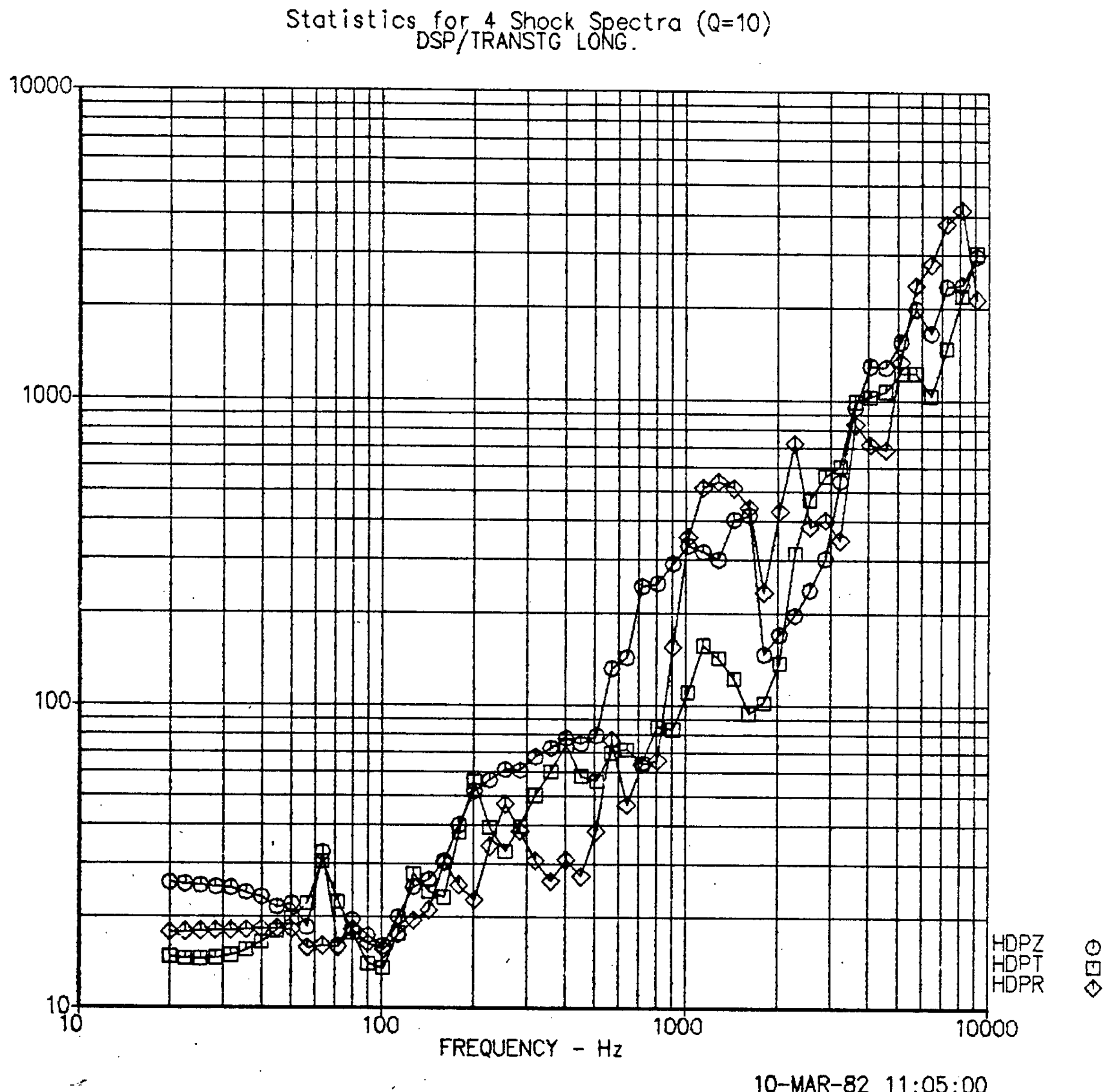
○ Axial, P95/50 of accelerometers 4Z, 32Z (HDPZ.P95)
□ Radial, P95/50 of accelerometers 4R, 32R (HDPR.P95)
◇ Tangential, P95/50 of accelerometers 4T, 32T (HDPT.P95)



TRANSTAGE LONGERON RESPONSE 4 IN. FROM INTERFACE
TO DSP SEPARATION NUT FIRING (S_T)
(1970 TEST)

○ Axial
□ Radial
◇ Tangential

CALC	OB	10MAR82	REVISED	DATE	FIGURE 5.1.3	
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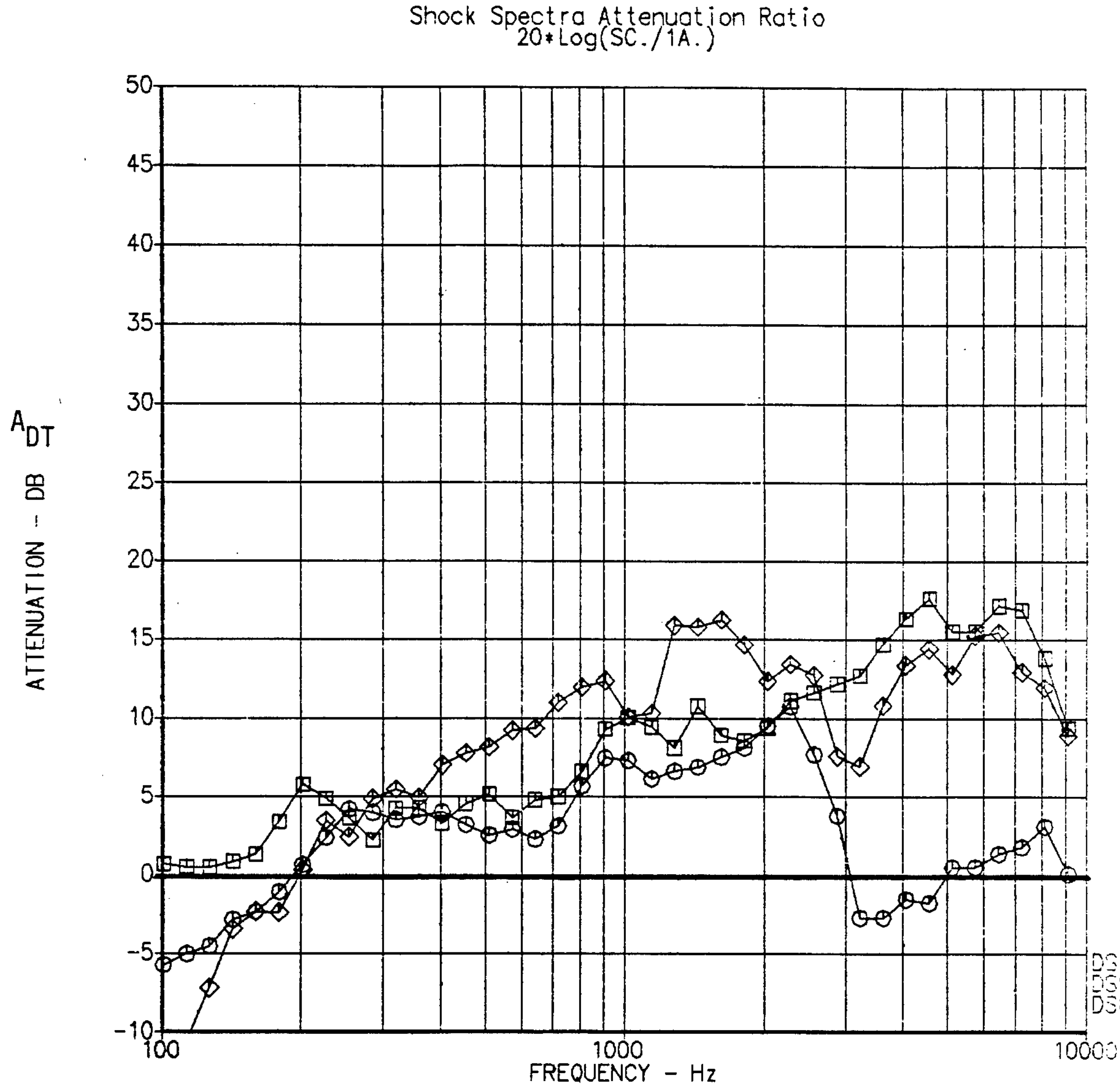
○ Axial
□ Radial
◇ Tangential

DSCA1*. = 20 log $\frac{HDSCB*}{HDSCS*}$

* = A, R or T



ATTENUATION

DSCS BIPOD FOOT/ TRANSTAGE LONGERON, 4 IN. FROM INTERFACE

(1981 TEST)

○ Axial
□ RAdial
◇ Tangential

CALC	CJB	5MAY82	REVISED	DATE	FIGURE 5.2.1	
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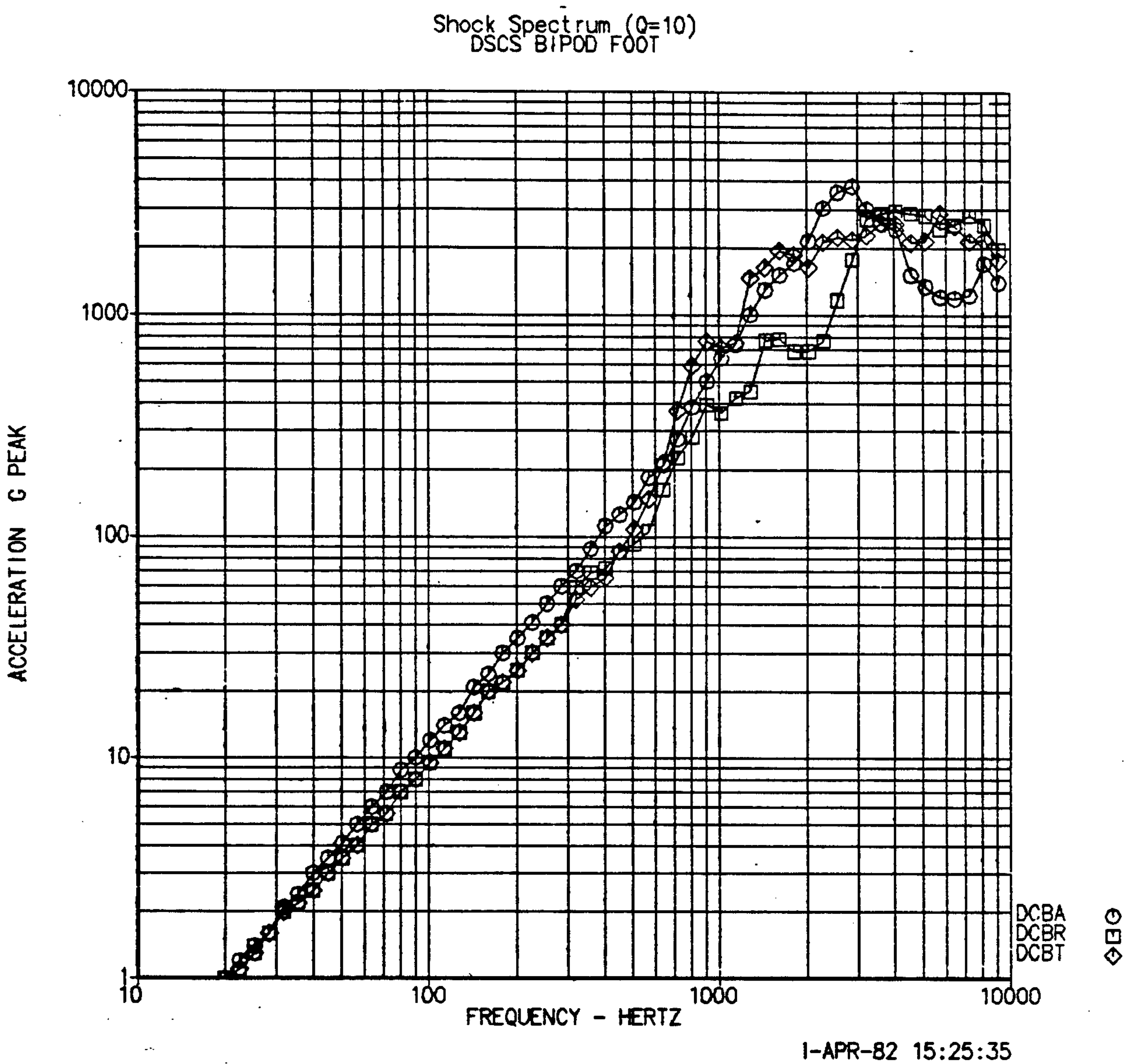

DSCS III INDUCED SHOCK
AT DSCS BIPOD FOOT

AXIAL
RADIAL
TANGENTIAL

(1981 DATA)

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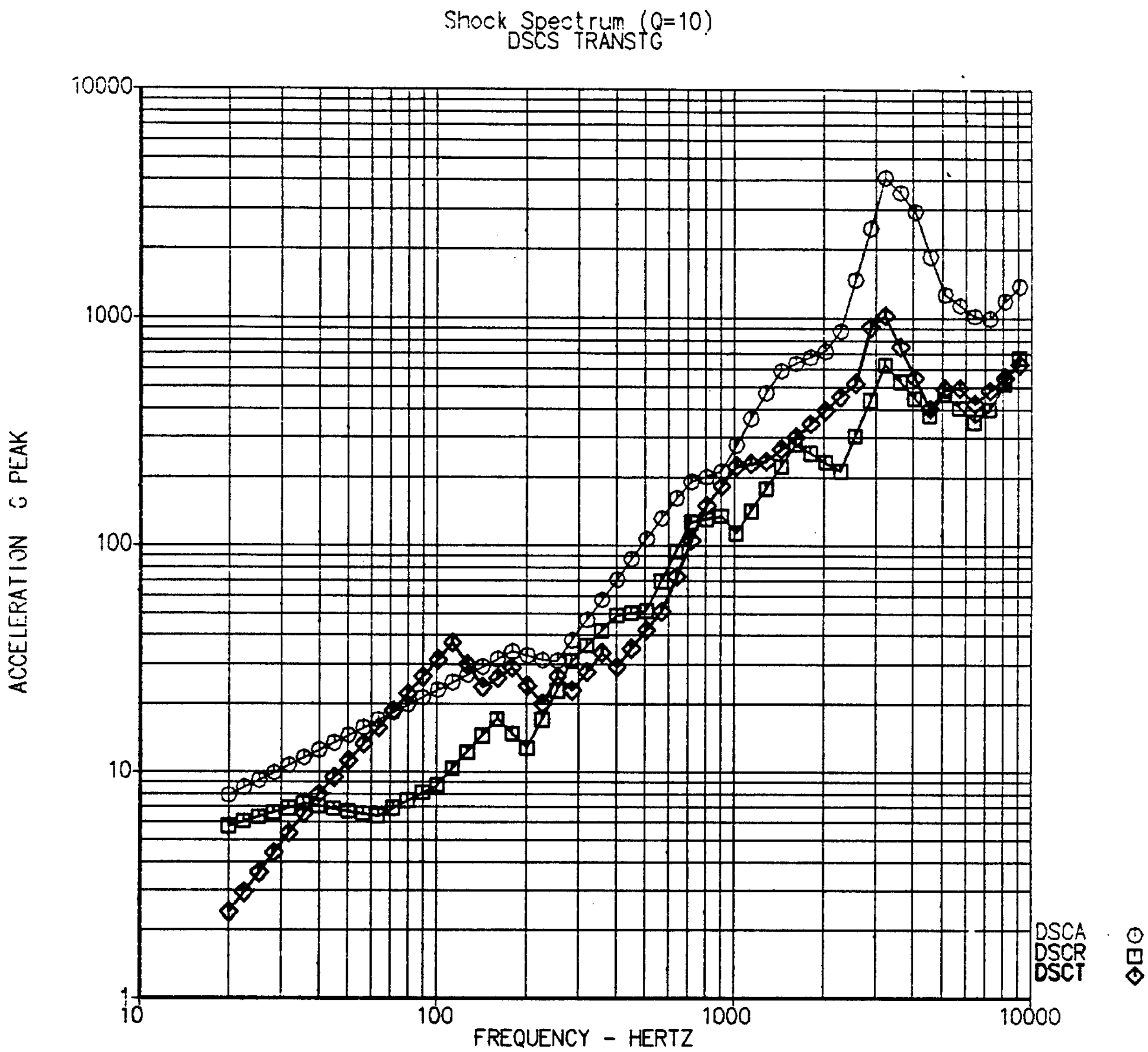


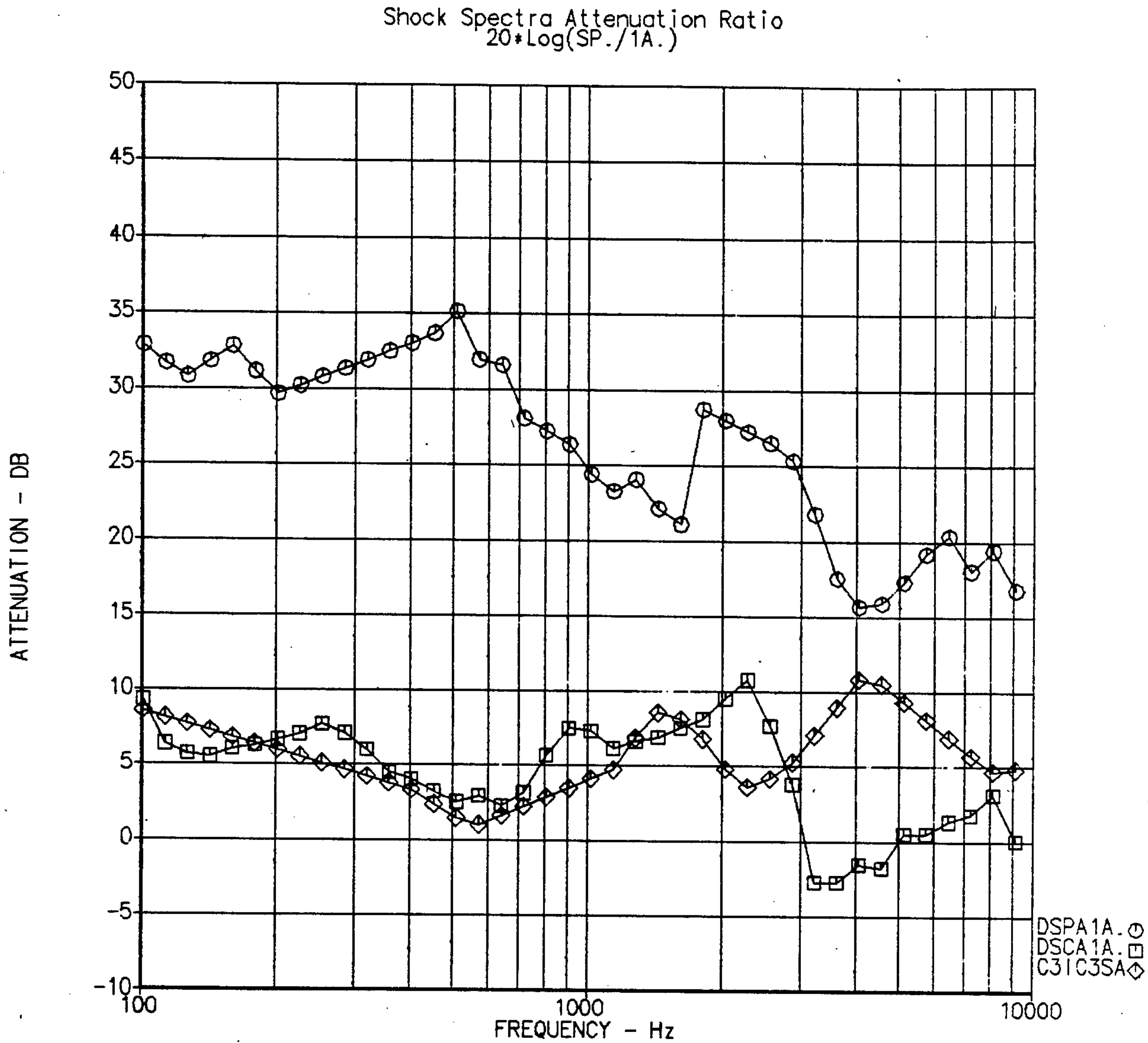
DSCS 3 INDUCED SHOCK
ON TRANSTAGE LONGERON
4 INCHES FROM INTERFACE (1981)

○ Axial
□ Radial
◇ Tangential

○ DSPA1A = 20 log $\frac{\text{HDSP12A.E}}{\text{HDPA.ENV}}$

□ DSCA1A = 20 log $\frac{\text{HDSCBA.ENV}}{\text{HDSCSA.ENV}}$

◇ C3IC3SA = 20 log $\frac{\text{HC3IA.ENV}}{\text{HC3SA.ENV}}$



ATTENUATION COMPARISON

○ DSP FITTING TO AC -2 LONGERON (11 IN,) 1970

□ DSCS FITTING TO AC-2 LONGERON (4 IN.) 1981

◇ IUS DTV NUT TO CS3 FOOT (16 IN.) 1980

AXIAL

CALC	CB	30APR82	REVISED	DATE	FIGURE 5.3.1	
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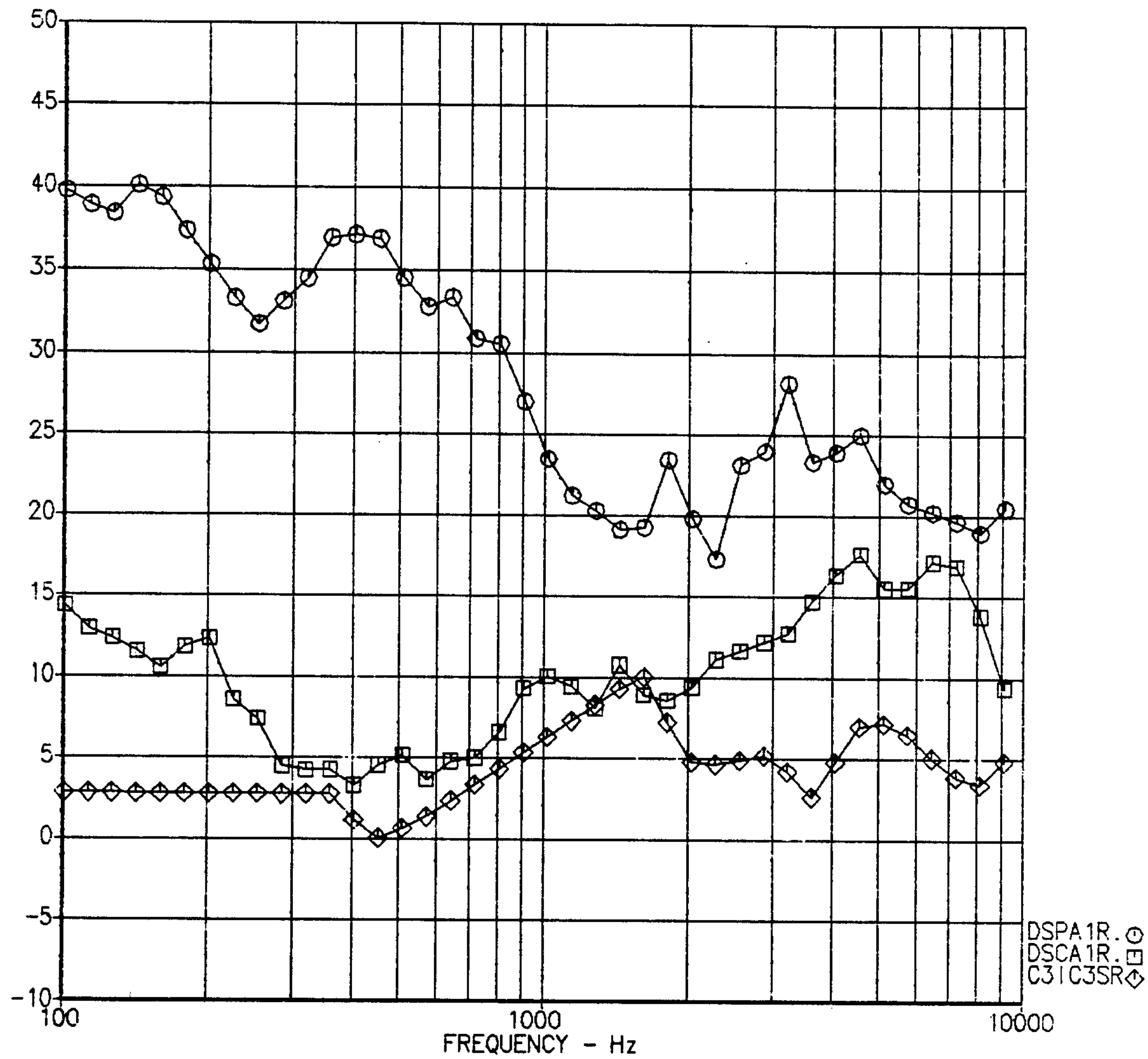
○ DSPA1R = 20 log $\frac{\text{HDSP12R.ENV}}{\text{HDPR.ENV}}$

□ DSCA1R = 20 log $\frac{\text{HDSCBR.ENV}}{\text{HDSCSR.ENV}}$

◇ C3IC3SR = 20 Log $\frac{\text{HC3IR.ENV}}{\text{HC3SR.ENV}}$



ATTENUATION COMPARISON

○ DSP FITTING TO AC-2 LONGERON (11IN.) 1970

□ DSCS FITTING TO AS-2 LONGERON (4 IN.) 1981

◇ IUS DTV NUT TO CS3 FOOT (16 IN.) 1980

RADIAL

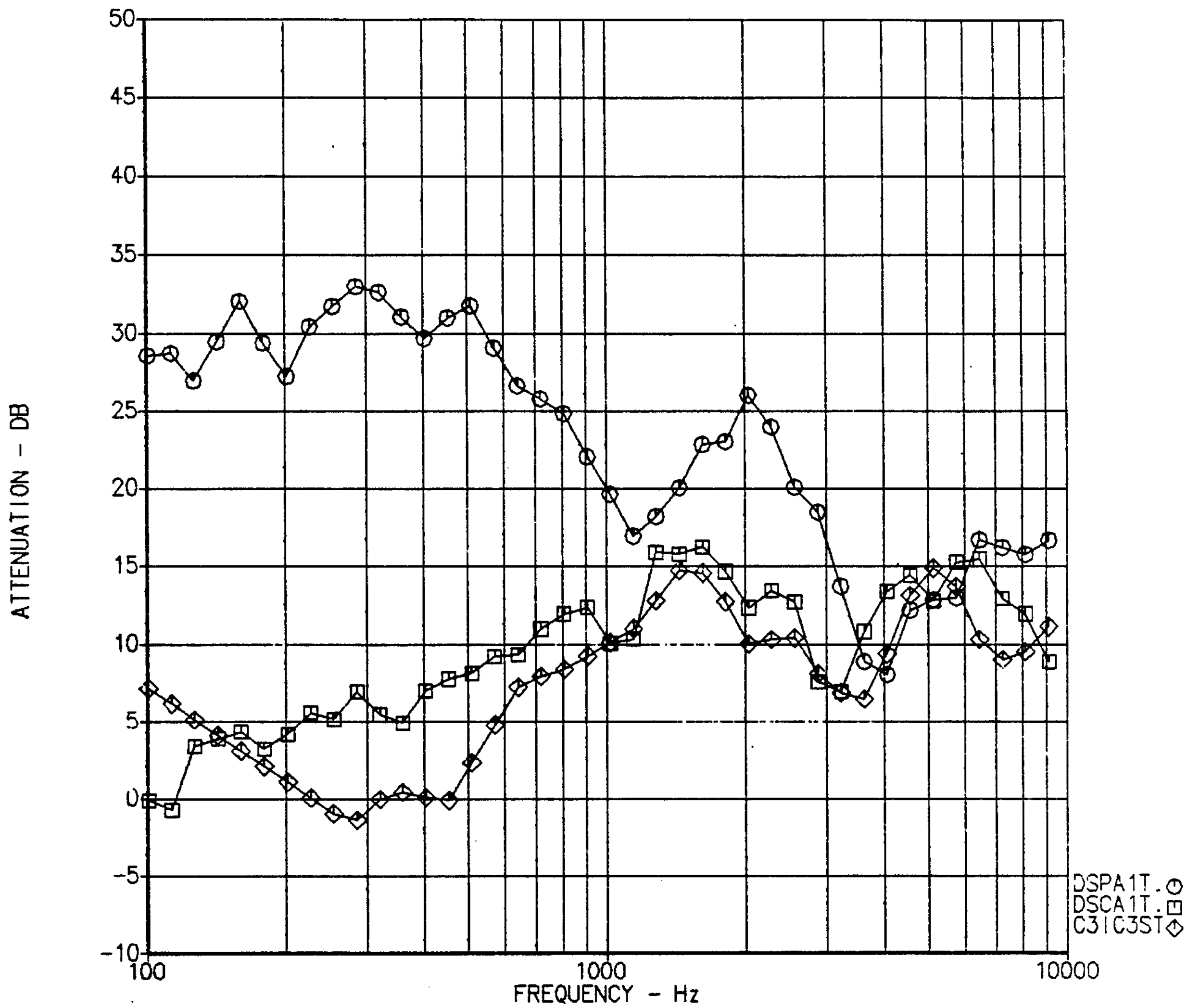
CALC		30APR82	REVISED	DATE	FIGURE 5.3.2	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-107

○ DSPA1T = 20 log $\frac{\text{HDSP12T.ENV}}{\text{HDPT.ENV}}$

□ DSCA1T = 20 log $\frac{\text{HDSCBT.ENV}}{\text{HDSCST.ENV}}$

◇ C3IC3ST = 20 log $\frac{\text{HC3IT.ENV}}{\text{HC3ST.ENV}}$

Shock Spectra Attenuation Ratio
20*Log(SP./1T.)



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ATTENUATION COMPARISON

○ DSP FITTING TO AC-2 LONGERON (11 IN.) 1970

□ DSCS FITTING TO AC-2 LONGERON (4 IN.) 1981

◇ IUS DTV NUT TO CS3 FOOT (16 IN.) 1980

TANGENTIAL

CALC	CJB	30APR82	REVISED	DATE	FIGURE 5.3.3 5.3.3		
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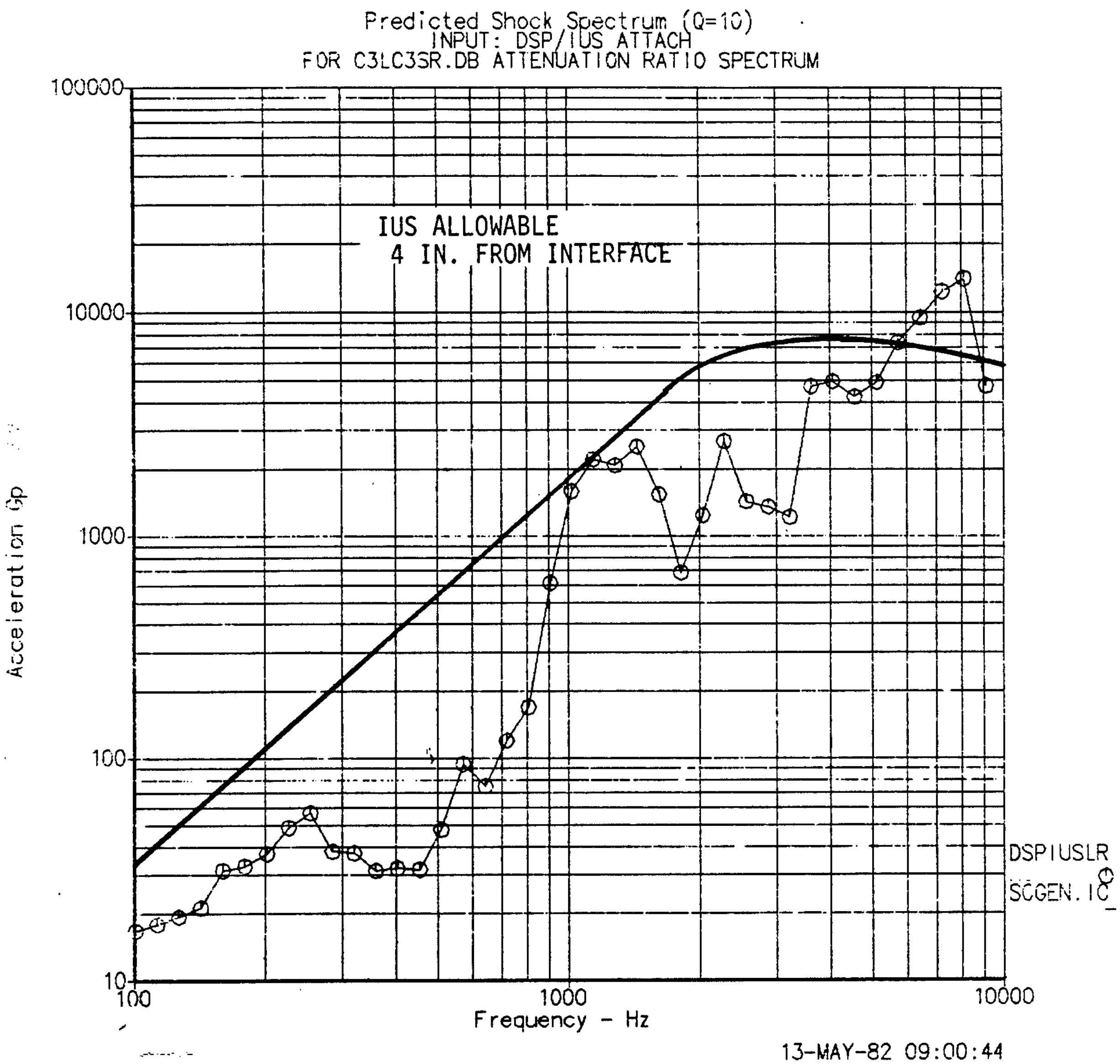
APPD.					THE BOEING COMPANY	PAGE	D-108

O DSPIUSLR. = S_s $(10^{-A1R/20})$



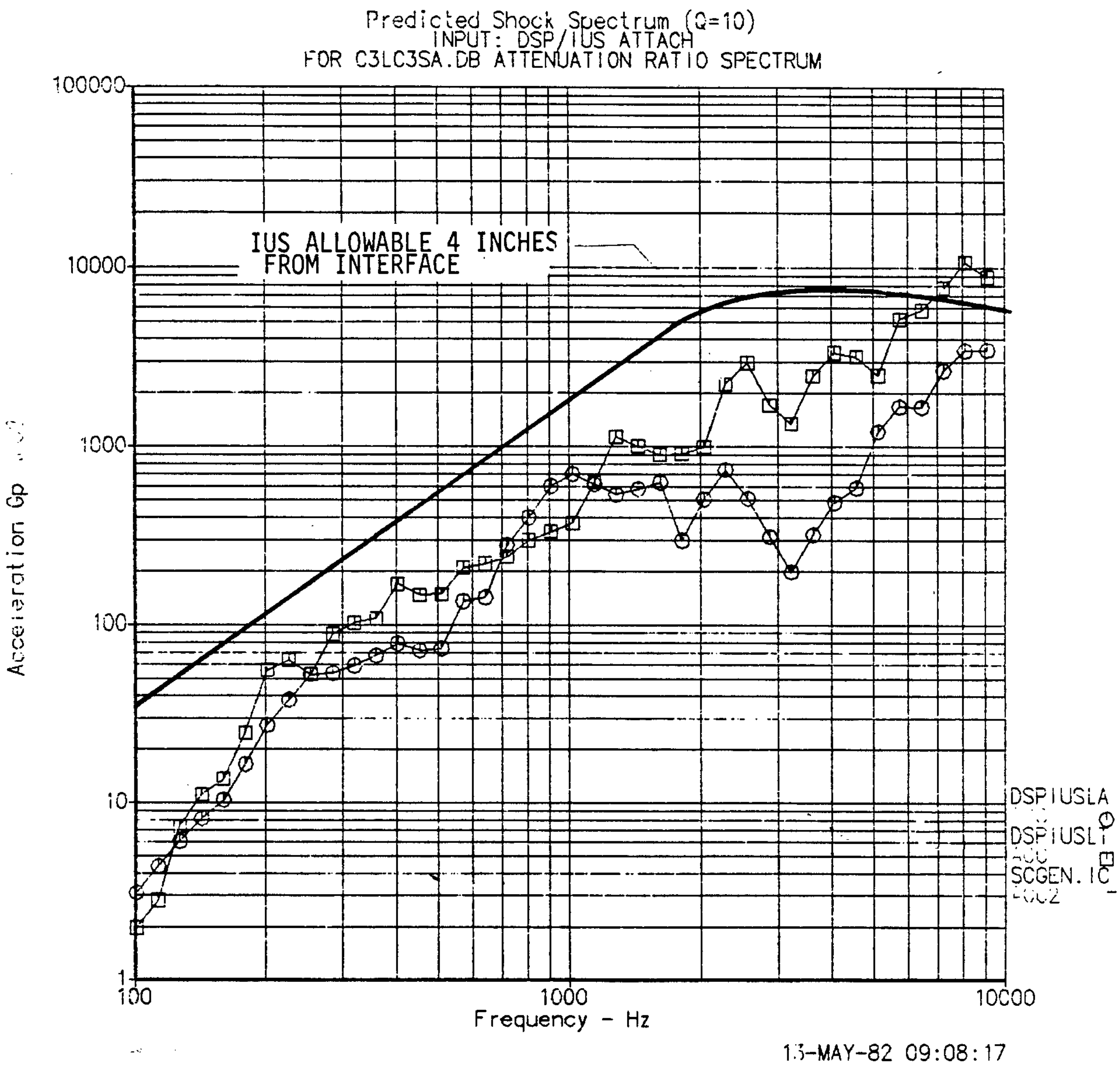
COMPARISON
DSP 12,13 INDUCED SHOCK
VS.
IUS ALLOWABLE
LOCATION ON IUS LONGERON, 4 INCHES FROM INTERFACE

RADIAL

CALC	OB	13MAY82	REVISED	DATE	FIGURE 5.4.1	
CHECK						
APPD.					THE BOEING COMPANY	PAGE D-109
APPD.						

$$\text{DSP IUSL*} = S_s\ (10^{-A1*/20})$$

$* = A$ or T



COMPARISON

DSP 12, 13 INDUCED SHOCK

VS.

IUS ALLOWABLE

LOCATION - IUS LONGERON, 4 INCHES FROM INTERFACE

O Axial

□ Tangential

CALC	CJB	13MAY82	REVISED	DATE	FIGURE 5.4.2	
CHECK						
APPD.						
APPD.					THE BOEING COMPANY	PAGE D-110

APPENDIX E
REVISED SHOCK ENVIRONMENT ASE/ORBITER

IRN 286 to ICD 2-19001 revised the shock environments at the ASE/Orbiter interface. The effect of the revision on ASE/Orbiter compatibility was evaluated and documented in Attachment B to Boeing memo 2-3612-IUS-087/88, Attachment B is presented in this appendix. Attachments A and C to 2-3612-IUS-087/88 are contained in D290-75303-1, Volume 3.

2-3612-IUS-087/88
Revision A
12 May 1988

TO:	W. R. Benshoof	8A-12
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	D. Wong	Aerospace Corp., M5/568
	R. C. Zaller	Aerospace Corp., M5/552

SUBJECT: Vibration and Shock Environment Evaluation, IRN 286 to ICD 2-19001

REFERENCE:
System Integration Problem N-39, title, N-39 IRN 286 to ICD 2-19001 Evaluation, dated 25 March 1988.

INTRODUCTION

IRN286 to ICD 2-19001 defines revised vibration and shock environments between ASE and the Orbiter. This memo contains an evaluation of the ASE component compatibility with the revised environments. The evaluation was conducted to resolve the reference system integration problem.

SUMMARY

~~The evaluation shows that the ASE components are compatible with the vibration environments defined by IRN286, Attachment A.~~

Attachment B shows that the ASE components are comptible with the shock environment defined by IRN286, and the ASE induced pyrotechnic shock is within the Orbiter allowable.

~~The low frequency vibration environments defined in IRN286 were determined to be less than the environments calculated using the IUS/TDRS-G/STS-26 dynamic loads model. A change to IRN286 is recommended in Attachment C.~~

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W. C. Gustafson
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IUS Dynamics

~~Attachment A Vibration Evaluation~~
Attachment B Pyrotechnic Shock Evaluation
~~Attachment C Dynamic Model Vibration Evaluation~~

ATTACHMENT B

IRN 286
PYROTECHNIC SHOCK EVALUATION

15 APRIL 1988

by Clark Beck

SCOPE/PURPOSE

IRN 286 adds paragraph 4.1.9 entitled pyrotechnic shock. Figure 1 presents paragraph 4.1.9 and associated shock spectra. The purpose of this evaluation is twofold:

1. to determine if the ASE induced pyrotechnic shock is within the shock envelope defined in figure 4.1.9.1-1 of IRN 286;

2. to determine if ASE components are compatible with the shock environment defined in figure 4.1.9.1-2 of IRN 286.

ASE INDUCED SHOCK

Three pyrotechnic events can occur on the ASE. These events are pin puller operation, Super Zip operation and pin pusher operation. Measurements have been made on the ASE to record the pyroshock events. The shock spectra resulting from these measurements are shown in figure 2. The shock spectra shown in figure 2 have been attenuated to determine the environment at the ASE/Orbiter interface. The IRN 286 payload induced allowable is also shown on figure 2. Figure 2 shows that the ASE induced shock is within the allowable specified by IRN 286.

ASE COMPONENT CAPABILITY

The nominal acceptance shock level for ASE components is shown in figure 3. The Orbiter induced allowable shock defined in IRN 286 is also shown in figure 3. Figure 3 shows that the ASE components are compatiblle with the Orbiter induced shock.

CONCLUSIONS

The pyrotechnic shock induced by the ASE at the Orbiter/ASE interface is less than the Orbiter allowable.

ASE components are compatible with the Orbiter induced shock.

FIGURE 1
IRN 286 PYROTECHNIC SHOCK REQUIREMENTS

4.1.9 Pyrotechnic Shock

4.1.9.1 Payload Induced Pyrotechnic Shock. The payload generated pyrotechnic shock detected on the trunnion at the payload to Orbiter interface shall not exceed the shock response spectrum shown in Figure 4.1.9-1. Payload generated pyrotechnic shock is not acceptable in the mid deck or the aft flight deck.

4.1.9.2 Pyrotechnic Shock From Other Sources. The maximum level of pyrotechnic shock detected on the trunnion at the payload to Orbiter interface transmitted from other payloads or Orbiter mounted equipment is shown in Figure 4.1.9.2-1.

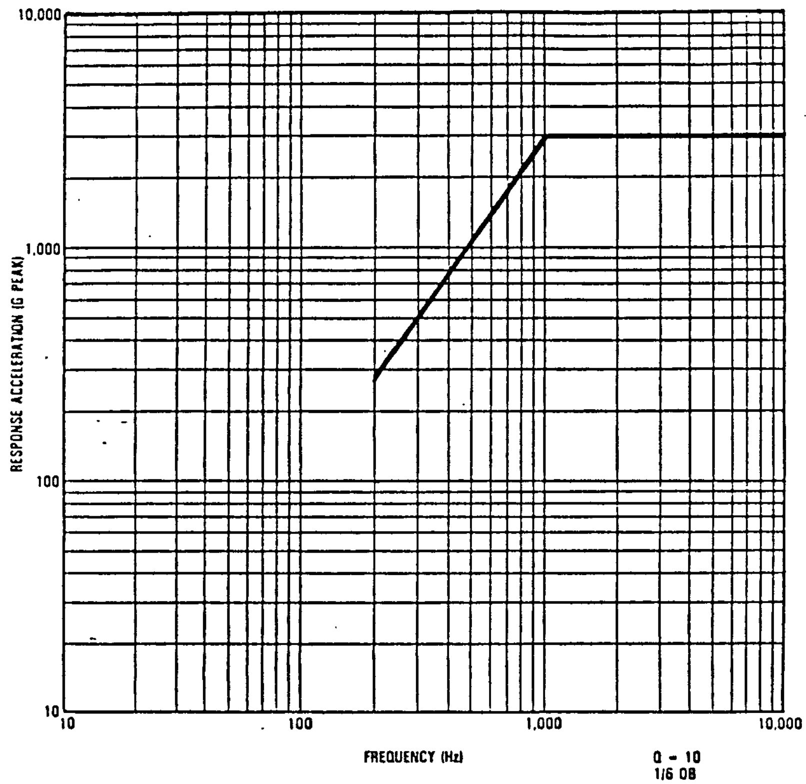


Figure 4.1.9.1-1 Orbiter/Payload Interface Shock Response Spectrum Payload Pyrotechnic Shock

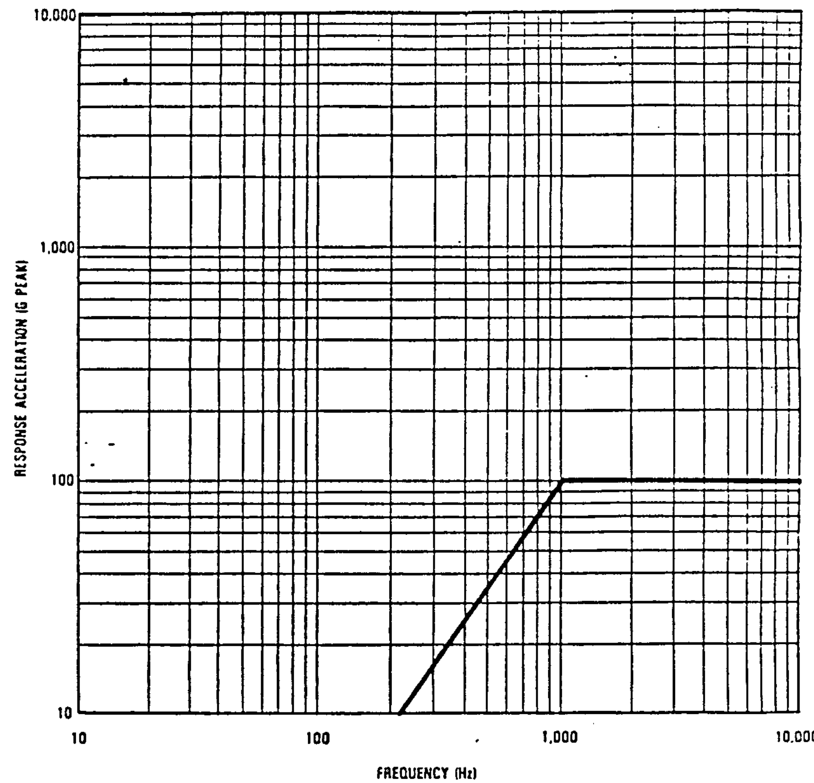
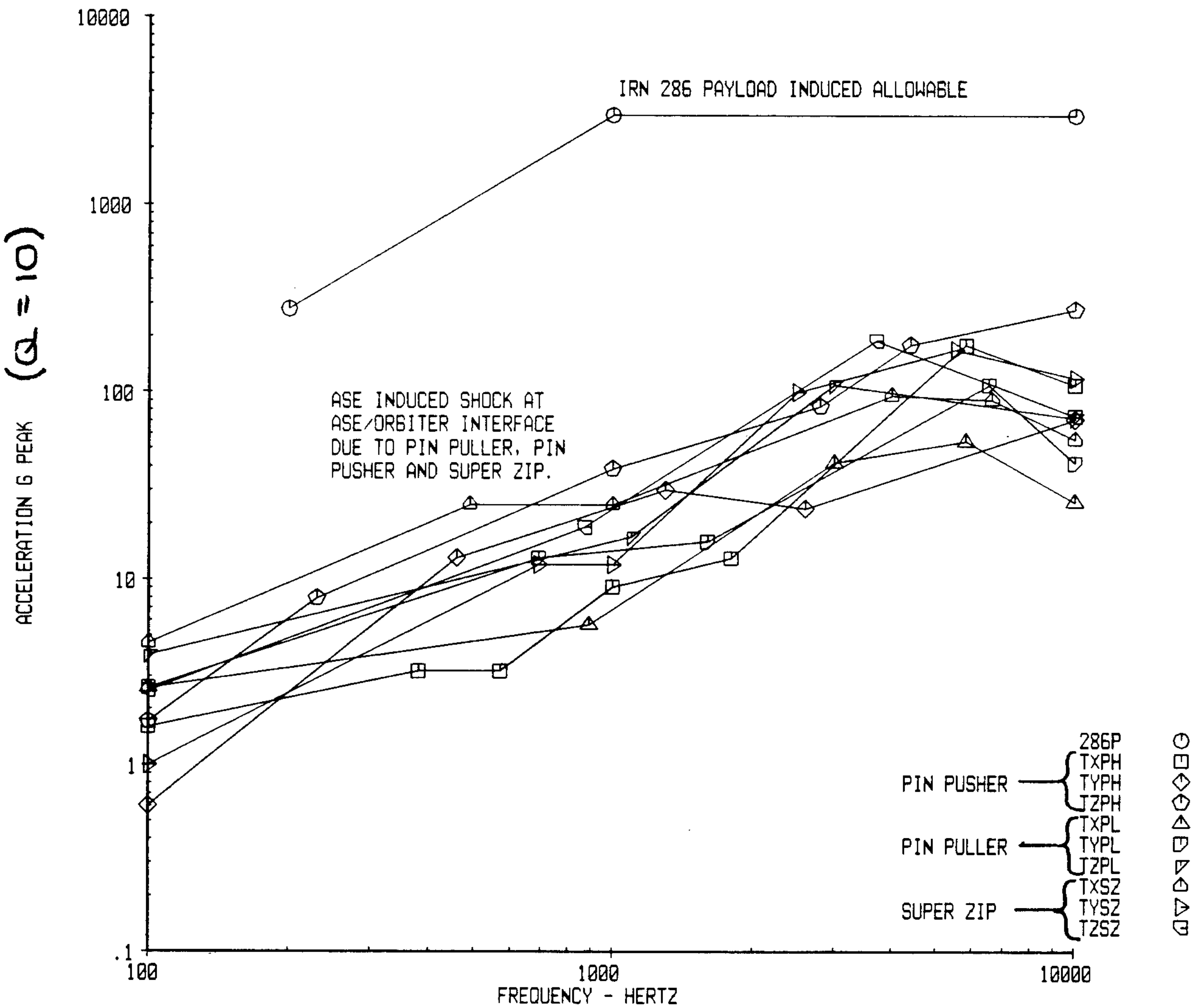


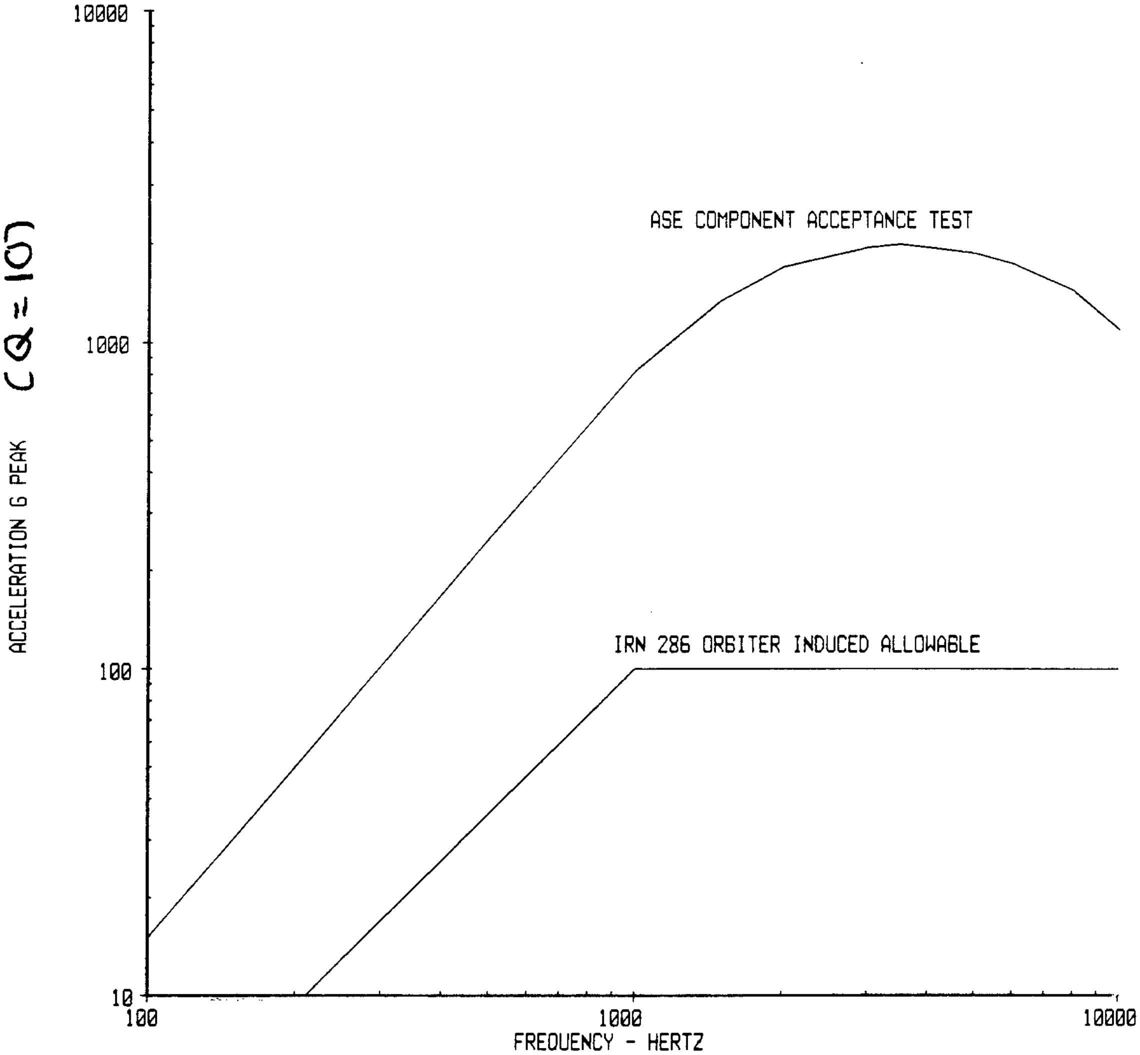
Figure 4.1.9.2-1 Orbiter/Payload Interface Shock Response Spectrum Orbiter

FIGURE 2
ASE INDUCED PYROTECHNIC SHOCK
LESS THAN IRN 286 PAYLOAD ALLOWABLE



ASE INDUCED SHOCK
LESS THAN ORBITER ALLOWABLE

FIGURE 3
ASE COMPONENTS COMPATIBLE
WITH IRN 286 ORBITER ALLOWABLE



ASE COMPONENTS COMPATIBLE
WITH ORBITER INDUCED SHOCK